USDOT Region V Regional University Transportation Center Final Report

NEXTRANS Project No. 0630Y03

IMPACT OF PUBLIC TRANSIT MARKET SHARE AND OTHER TRANSPORTATION VARIABLES ON GHG EMISSIONS: DEVELOPING STATISTICAL MODELS FOR AGGREGATE PREDICTIONS

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ACKNOWLEDGMENTS AND DISCLAIMER

Partial funding for this research was provided by the NEXTRANS Center, Purdue University under Grant No. DTRT07-G-005 of the U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), University Transportation Centers Program. Additional funding was provided by The Ohio State University (OSU) including the College of Engineering and the Department of Statistics.

The efforts of Graduate Research Assistants Andrew Landgraf and Ashley Westra are greatly appreciated.

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1. INTRODUCTION AND MOTIVATION

Policies that encourage reduced travel, such as traveling shorter distances, and increased use of more efficient transportation modes, such as public transportation and high-occupancy private automobiles, are often considered one of several possible tools aimed at improving the sustainability of transportation. This study develops a statistical model that provides an important step towards quantifying the possible benefits that could be derived from such policies in terms of potential reductions in greenhouse gas (GHG) emissions.

In general, passenger transportation related energy consumption and GHG emissions per capita in urbanized areas are expected to be dependent on the supply and demand characteristics of the multiple modes of passenger travel in these areas. Naturally, an overall reduction in travel leads to lower GHG emissions. Moreover, due to the efficient nature of public transportation and the greater flexibility this mode offers in using different sources of energy, it is expected that, in general, an increase in the use of transit services could lead to a reduction in GHG emissions. Similarly, higher private vehicle occupancy is expected to mitigate the negative impacts of the single-occupancy vehicle mode, again in the form of reduced GHG emissions. Furthermore, population density has the potential to contribute to reduced travel and the adoption of policies and services that encourage more efficient modes. In addition to understanding the explanatory effects of transportation mode choice, the supply of transportation services, and population density, it is equally important to take into account the direct or indirect effects of government policies aimed at reducing GHG emissions.

In this study, only CO_2 emissions are examined since these emissions constitute 93.4% of the GHG produced in the transportation sector (Energy Information Administration, 2008). In addition, the CO_2 emissions focused on are those resulting from passenger travel and the roles of travelers' choices within the confines of available infrastructure and existing urban form. Therefore, unlike other studies, freight transportation is not considered. Moreover, CO_2 emissions resulting from the construction of transportation infrastructure and the manufacturing of passenger vehicles (private and public) are outside the scope of this study. In contrast, other studies focus on the total life-cycle CO_2 emissions – see, for example, Chester and Horvath (2009). The rationale motivating the marginal nature of the scope of this study is the desire to quantify the relative changes in CO_2 emissions that could result from policies directly aimed at urban passenger transportation, a common situation that policy-makers face.

The contributions of this study are twofold. First, an aggregate model of urban passenger travel related CO_2 emissions in US urbanized areas that includes a rich set of explanatory variables is developed. Second, in doing so, the roles of policies aimed at improving the environment or could enhance the attitudes of travelers towards making environmentally favorable choices is captured through the use of a proxy variable.

2. MODEL DEVELOPMENT

2.1 Data and Variables

The response variable of interest is the annual metric tons of CO_2 per capita emitted in an urbanized area in the US as a direct result of passenger transportation using all modes of travel. The explanatory variables considered in this study are transit share, transit service utilization, average vehicle occupancy, lane miles per capita, average travel time, population density, degree of variation in population density, and the presence or absence of an automobile emissions inspection program. The involved process of determining the values of these variables and creating an integrated cross-sectional dataset from multiple sources for the largest 146 urbanized areas in the US for the years 2000-2003 is described in Mishalani and Goel (2011). The explanatory variables described next are available in this dataset and are considered and used in the model estimation because it is believed that they could play important roles in explaining the levels of passenger travel related CO_2 emissions in urbanized areas.

The response variable of interest, CO_2 emissions per capita resulting from passenger travel, was calculated from the energy used by the various modes based on the conversion equations provided by the US Environmental Protection Agency (US EPA, 2010). The energy consumption from private automobile travel for each urbanized area was calculated based on the vehicle-miles attributable to this travel multiplied by the fuel efficiency across the different classes of vehicles, weighted by their prevalence. Energy consumed by transit fleets is reported in the Federal Transit Administration’s national transit database (NTD, 2010).

Transit share is represented by the ratio of passenger-miles traveled using public transportation services to the total passenger miles traveled. Given that CO_2 emissions are dependent on energy consumption, which in turn is dependent on distance traveled, it is important to include the distance traveled in this transit share variable. Due to the efficiencies that transit could offer, an increase in this variable is expected to result in a reduction in CO_2 emissions. An alternate transit share variable defined by the ratio of transit passenger trips to total passenger trips is also considered. Transit service utilization, as measured by the ratio of passenger miles traveled on transit to the total space-miles provided (a “space” represents capacity that could be occupied by a prospective passenger), is another important variable because if transit utilization is low, the advantages offered by the mass use of public transportation would be lost. Therefore, an increase in transit utilization is expected to reduce CO_2 emissions.

The supply of infrastructure enabling travel by private automobiles could also have an important effect on CO_2 emissions. This variable is measured by freeway lane-miles per capita. A greater supply of freeways for private automobile use is likely to increase the reliance on this mode, producing higher CO_2 emissions as a result. Private automobile occupancy, on the other hand, would have the opposite effect because the marginal increase in energy consumption and resulting CO_2 emissions due to additional passengers in a private automobile is very low.

Average commute travel time across all modes is expected to be pertinent because an increase in this variable is likely to lead to an increase in CO_2 emissions due to the implied longer trips travelers take in an urbanized area. Average travel distance is not adopted as an alternative explanatory variable because, as discussed previously, vehicle-miles attributable to private automobile travel are used in the calculation of the dependent variable CO_2 per capita and, therefore, it is inadvisable to directly include average travel distance as an explanatory variable. Population density is of interest because an increase in density enables policies and services that could lead to more travelers traveling shorter distances, using public transportation, and sharing private vehicles leading to lower CO_2 emissions per capita. In addition, the coefficient of variation (CV) of population density – the ratio of the standard deviation of density to the mean of density where the standard deviation is calculated on the basis of the densities of zip code sectors within urbanized areas – was also considered based on the premise that a large value indicates that a disproportionately large percentage of the population could be living in a smaller part of the urbanized area, thus, likely leading to shorter travel distances resulting in reduced CO_2 emissions.

Since urbanized areas may institute certain policies that have direct or indirect impacts on reducing GHG emissions, the use of a proxy for such policies is considered in this study. A readily available proxy variable is the binary indicator of whether urbanized areas have regulations in place that require that vehicles are inspected for emissions on a regular basis (usually annually) and are maintained if emissions levels exceed specified thresholds. While these inspection programs are federally mandated to address emissions of pollutants – such as hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and volatile organic compounds (VOCs) – and not GHG emissions (Rilett, 2002), the presence of such inspections in an urbanized area could be viewed as a proxy indicator of the presence of other policies and regulations aimed at mitigating environmental concerns, some of which could be related to GHG emissions. While the Clean Air Act amendments of 1990 mandated all cities that do not meet federal health standards to implement emission inspection programs, the majority of the cities (70 of 110) that were required to implement the inspections in 1990 already had such programs in place, indicating that the policy-makers of many of these cities were conscious of and acted proactively to curb the effects of pollution prior to the 1990 mandate (Almanac of Policy Issues, 2002). Such policy actions may have already been extended to address GHG emissions as well. The presence of inspection programs may influence policy-makers by highlighting the environmental costs of transportation leading to their adopting a more aggressive stand in relation to environmental issues in general, including GHG emissions.

To illustrate the proxy nature of the inspection variable in terms of its ability to indicate the presence of other policies or regulations that have an effect on GHG emissions, consider the specific case where certain states adopted the California Air Resources Board (CARB) standards, which include improved fuel efficiency aimed specifically at reducing GHG emissions. While none of these GHG standards were in effect in 2000 (DieselNet, 2011), the year corresponding to the automobile inspection proxy variable in the dataset used, it is worthwhile to explore the degree of association between the presence of automobile inspection programs in 2000 and the adoption of CARB standards by 2011 (Center for Climate and Energy Solutions, 2011). Of the 70 cities that had inspection programs in 2000, the states of 41 (59%) adopted CARB standards by 2011. Of the 76 that did not have inspection, only 8 (11%) adopted these standards. The Chi-squared test for independence of these two variables has a p-value of 2.425 10-9, indicating that there is a very strong association between the two variables.

In addition to inspection providing a possible indication of other policies and regulations, it could also have a favorable effect on the attitudes of travelers by raising awareness, possibly causing them to make better choices regarding the miles per gallon (MPG) levels of vehicles they purchase, drive in a manner that produces less CO_2 emissions, or select more efficient travel modes such as public transportation and high occupancy private automobiles. Gaker et al. (2011) found that people are willing to change their travel behavior to reduce CO_2 emissions, even if doing so comes with a higher personal cost in terms of time or money.

2.2 Model Specification and Estimation Results

The first step taken to specify and estimate a model of CO_2 emissions per capita as a function of the aforementioned explanatory variables was to use an all-possible regressions technique to compare the estimated linear regression models across all subsets of the explanatory variables. Various interactions between variables were also considered in this approach. In all the considered specifications, the population density variable is transformed to 1/density as a result of the nonlinear and negative relationship between CO_2 per capita and density as determined in the exploratory analysis conducted in Mishalani and Goel (2011). This transformation is maintained for all specifications discussed subsequently.

After comparing numerous model specification estimates, it was determined that the explanatory variables that contribute to CO_2 per capita levels in a statistically significant manner are transit share, lane miles per capita, average travel time, average vehicle occupancy, and 1/density. Since it is believed that the implementation of an emissions inspection program can be viewed as a proxy for the presence of other policies and regulations aimed at mitigating GHG emissions and may encourage favorable travel choices that could lead to reduced GHG emissions, an indicator variable representing the presence of an automobile emissions inspection program in an urbanized area is also included in the model. This variable takes the value of one for urbanized areas with an emissions inspection program and zero otherwise. The estimation results of this linear regression model are presented in Table 1. The estimated coefficients of all of the explanatory variables have the expected signs along the lines of the discussion in Section 2.1.

TABLE 1: Estimation results of linear regression model for CO_2/capita

Explanatory variable	Coeff	Std err	t-stat	p-value
Constant	2.285	0.622	3.674	<0.001
Transit Share	– 2.697	1.436	– 1.878	0.062
Freeway Lane-mi/capita	676.823	93.456	7.242	<0.001
Average Travel Time	0.046	0.008	6.066	<0.001
Avg. Priv. Veh. Occupancy	– 1.999	0.540	– 3.699	<0.001
1/Density	383.362	177.083	2.165	0.032
Emissions Inspections Indicator	– 0.016	0.048	–0.325	0.746
# of observations = 146; R^2 = 0.502				

While the estimated coefficient of the indicator variable for emissions inspections does have a negative sign, suggesting that the presence of inspections is associated with lower CO_2 per capita in an urbanized area, it is not found to be statistically significant. That is, the estimated model shows that simply adding a binary variable indicating whether or not an urbanized area has an emissions inspection program in place does not improve the model (the coefficient estimates and their statistical significance are similar to those of a model where the indicator variable is not included in the specification), even though this variable is hypothesized to have an explanatory effect on CO_2 per capita.

3. NEXT STEPS

The insignificance of the estimated coefficient of the inspection indicator variable could be due to the possible presence of two relationships involving automobile emissions inspection programs and CO_2 emissions that counter the effects of one another. While the presence of an inspection program in an urbanized area could be indicative of other policies and regulations that reduce GHG emissions, adopting an inspection program in an urbanized area aimed at reducing pollutants emissions levels and adopting other policies aimed at reducing GHG emissions in the same urbanized area are likely to be partly driven by the presence of environmental concerns in that area associated with higher levels of CO_2 emissions. Therefore, a possible self-selection into an emissions inspection category may be at play among the urbanized areas in the dataset due to this simultaneity, thus, leading to a selectivity bias in the model's coefficients estimates presented in Table 1. Therefore, it is critical to investigate this possible self-selection and address it to improve the model specification and estimation in subsequent efforts.

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