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Associations among household characteristics, vehicle characteristics and emissions failures: An application of targeted marketing data

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ABSTRACT

Many U.S. cities use vehicle emissions testing programs to improve air quality by identifying gross polluting vehicles and requiring their owners to make emissions-related repairs. All vehicles that meet certain criteria must pass an emissions test as part of the vehicle registration process. States use different criteria to determine which vehicles must be tested; however, the equity impacts associated with various screening criteria are unknown. This is due to difficulties researchers have faced in linking vehicle and household characteristics. We investigate the relative influence of vehicle and household characteristics on emissions failures in Atlanta, Georgia, by linking its emissions testing database to a targeted marketing database; the latter contains information about vehicle owners. We use count and hurdle models to predict vehicle emissions failures. Our model finds a relationship between sociodemographic characteristics and emissions failures after controlling for vehicle characteristics; that is, given two identical vehicles, the one owned by a low-income or minority household is more likely to fail emissions. We use our model to investigate the impacts of different emissions testing policies by income and ethnic groups.

1. Introduction

Urban air pollution, one of today's major environmental problems, is largely due to transportation-related emissions. In 2010, highway vehicles and non-road mobile sources were responsible for about 57% of the carbon monoxide (CO), 55% of the nitrogen oxide (NOx), 33% of the volatile organic compounds (VOCs), and 27% of the particulate matter (PM) emissions in the U.S. (Office of Air Quality Planning and Standards, 2012). The transportation sector is the second largest producer of greenhouse gases (GHG) in the U.S. after the industrial sector: in 2003, the transportation sector accounted for 27% of total GHG emissions (Office of Transportation and Air Quality, 2006).

As a result of the 1990 Federal Clean Air Act, the Georgia's Clean Air Force (GCAF) Program, also known as the Georgia Vehicle Inspection and Maintenance (I/M) Program, was created in 1996. The main purpose of this program is to identify high-polluting vehicles and require their owners to repair these vehicles so they meet minimum emissions standards. The program requires all gasoline-powered cars and light-duty trucks (except the three most recent model years and model years older than 25 years) that are registered in the thirteen non-attainment metropolitan Atlanta counties to undergo an annual emissions test.

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However, I/M programs have been criticized since their inception (Washburn et al., 2001). Several authors have raised concerns about the accuracy and reliability of I/M test results, noting that real-world driving conditions are different from those used at I/M facilities (Calvert et al., 1993; LeBlanc et al., 1993). Therefore, it is possible that some vehicles that pass emissions tests are in reality gross polluters. A related concern is that emissions have been shown to vary substantially across multiple tests (Bishop et al., 1996). This can lead to a large number of false positive or false negative results and encourage individuals to try to "game" the emissions testing system and avoid repairing high-polluting vehicles by having these vehicles tested multiple times until they (finally) record a "pass."

Despite criticism about the reliability and accuracy of I/M programs, states are still inclined to maintain these programs. This is because states that have non-attainment areas may face fines or penalties from the U.S. Environmental Protection Agency (EPA) if they do not demonstrate that they are making efforts to address their air quality issues (Washburn et al., 2001). Nationwide, more than half of the states have emission testing policies that are based on vehicle characteristics and, in some cases, include economic hardship waivers for repairs for low-income households and/or seniors. Within Georgia, the GCAF program was able to identify and repair about two million heavy polluting vehicles between 1996 and 2011 (Georgia's Clean Air Force, 2012), which enabled the state to demonstrate that it was actively working towards achieving the Clean Air Act goals.

A second criticism of I/M programs relates to their cost-effectiveness, as every vehicle that meets certain criteria has to indiscriminately undergo inspection. According to a report by the National Academies (Committee on Vehicle Emission Inspection and Maintenance Programs, 2001), about 50% of carbon monoxide and hydrocarbon emissions come from 10% of the vehicles. A number of studies based on statistical analysis of data from I/M emissions tests have shown that vehicle characteristics are associated with I/M failures (Beydoun and Guldmann, 2006; Choo et al., 2007; Washburn et al., 2001). According to these studies, factors such as model year, number of engine cylinders, odometer reading, vehicle manufacturer, fuel type, and presence of on-board modern emissions control systems can be used in predictive models to help identify potential high-emitting vehicles. However, although "vehicle characteristics are the most influencing factors affecting hydrocarbon and carbon monoxide emissions [...], the second most influencing construct is the driver/rider demographics" (Chiou and Chen, 2010). A few studies that have examined associations between socioeconomic criteria and vehicle emissions include one by Chiou and Chen (2010) based on 748 observations that directly linked disaggregate household-level socioeconomic criteria with vehicle emissions, and one by Singer and Harley (2000) that used a fuel-based approach to estimate vehicle emissions and linked emissions to income levels computed from census data resolved at the zip code level.

Our paper jointly considers the impact of vehicle characteristics and household demographics on emissions failures by linking a targeted marketing database that contains household characteristics to the 2010 Atlanta I/M emissions test database maintained by the Georgia Department of Motor Vehicles. After merging these databases, we have more than 250,000 records of households in the Atlanta area; this represents a substantially larger sample of disaggregate vehicle and household characteristics than samples used in prior studies.

The objective of this paper is to understand how household demographics, vehicle characteristics, and interactions among demographics and vehicle characteristics are associated with emissions failures. This objective is consistent with prior studies published in *Transportation Research Part A* that have examined one or more aspects of emissions modeling (e.g., Beck et al., 2013; Bureau and Glachant, 2008; Poudenx, 2008; Rogan et al., 2011). Hurdle models are used to examine whether a vehicle passes or fails its emissions test and, if it fails its emissions test, how many repeat tests are conducted before the vehicle passes. We use our estimated model to evaluate three potential emission testing policies for Georgia: (1) exempting vehicles less than five years old from testing; (2) providing vehicle maintenance subsidies to low-income households; and, (3) offering rebates for trading in an older vehicle and purchasing a newer, more fuel-efficient vehicle.

The paper is organized into several sections. Section 2 provides an overview of the data. Sections 3–5 discuss the modeling methodology, results, and validation, respectively. Section 6 uses the results of our models to evaluate impacts of different emissions testing and vehicle replacement policies. The paper concludes with a summary of the main findings and directions for future research.

2. Data

Our analysis database was compiled from three different sources: (1) the 2010 Georgia's Clean Air Force Inspection/Maintenance (GCAF I/M) emissions test results for vehicles in the 13 non-attainment counties in the metro Atlanta area; (2) the vehicle registration database maintained by the Georgia Department of Motor Vehicles (DMV); and, (3) the targeted marketing (TM) records of a consumer credit reporting agency. Although the two first data sources are commonly employed for transportation modeling, the use of TM records is only recently developing (Kressner and Garrow, 2012).

2.1. Georgia's Clean Air Force Inspection/Maintenance database

In Georgia, every gasoline-fueled car and light-duty truck with a gross vehicle weight rating of 8500 pounds or less registered in one of the 13 non-attainment metro Atlanta counties has to pass an annual emissions test in order to obtain or maintain registration (Georgia's Clean Air Force, 2012; Office of Inspector General, 2006). The three most recent model year vehicles are exempt from emissions testing, as are vehicles that are 25 years or older. Emissions test results for 2010 were