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DETERMINANTS OF MARTA RIDERSHIP: HOW GAS PRICES, INCOME, AND RACE AFFECT PUBLIC TRANSIT USE IN ATLANTA

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An abstract of
A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Arts with Honors

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Abstract

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As global warming and economic recession become increasingly eminent problems in contemporary society, policymakers have begun to look towards alternative forms of transportation as a means of creating jobs for American workers and reducing the United States' impact on the environment. During the 1970s, many economists studied the costs and benefits of public transit; however, until recently, literature on the subject has been much less robust. This paper contributes to the fields of applied microeconomics and urban transportation studies by containing a three-part analysis on the impact of fuel prices on ridership of Metropolitan Atlanta Rapid Transit Authority (MARTA) bus and rail systems. Using time series and fixed effects regressions, this study finds that rising fuel costs lead to increased ridership on public transportation in the short term. It also shows with maps created using Geographical Information Systems (GIS) programs that demographic factors, such as race and income, play significant roles in determining public transit usage in Atlanta.

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Last summer, I commuted to my internship in Downtown Atlanta by riding MARTA's East Line from Edgewood/Candler Park to Five Points. Traveling home after my first day of work and exhausted from standing on the train, I stumbled as the MARTA train came to an abrupt halt; my cell phone launched itself from my hands at the sudden change of direction and split into several pieces, which quickly scattered themselves to all corners of the car. A little upset, I nevertheless bent to collect the remains of my cell phone and was shocked when every person—seated or standing—turned to help me. What was my lonely search for the small objects became a car-wide quest, and my astonishment with my fellow riders' generosity and their desire to assist someone else, as well as a newfound sense of this transit community, led me to decide right then and there that I would write my thesis on public transportation in Atlanta and the factors that determined MARTA ridership. So, thank you to the people who shared my rail car that day: without your kindness, I am not sure that I would have chosen this path.

Of course, there are a number of other people who influenced my decision and supported my choice to write a thesis. I owe them a large debt of gratitude for listening to my complaints and helping me when I needed it. In no particular order…

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I. INTRODUCTION

As global warming and economic recession become increasingly eminent problems in contemporary society, policymakers have begun to look towards transportation reform as a way of creating jobs for American workers and reducing the United States' impact on the environment. One option for reform is public transit, a system of bus and rail networks connecting homes and jobs, suburbs and cities. In her study on the advantages and challenges posed by public transportation, Dr. Robyn Gershon, a professor at Columbia University's Mailman School of Public Health, cites its positive effect on the economy. Current and potential employees use public transit as a means of commuting to work or to job opportunities. For those without access to a car, publicly-provided buses and trains become a form of economic and political empowerment: they are no longer geographically bound to a certain type of employment. Employers located near transit stations gain increased workforce accessibility, and often times, the presence of a transit station will revivify commercial and residential development in the surrounding area, because businesses are assured of both customer and employee bases. Average office rents near rail stations increase with rising ridership, and vacancy rates are lower (Cervero, 1992). Communities where transit ridership rates are high devote less property to parking, resulting in greater economic returns to real estate investments and elevated property values. Elevated property values, in turn, lead to more taxes paid to state governments, which are then distributed as subsidies for programs aimed at helping the general public. By virtue of rising employment levels, state governments are also able to allocate funds normally used for unemployment benefits to other sectors. Thus, public transportation has a cyclical effect on the economy, stimulating it by facilitating interaction on labor and real estate markets.

Public transportation usage also has a positive impact on the environment. According to the American Public Transportation Association (APTA), public transit saves the United States 4.2 billion gallons of gasoline each year (or 11 million gallons per day), thereby curtailing American expenditures on fuel. In 2005 it reduced carbon emissions by 16.2 million metric tons, while only producing 12.3 million metric tons.[1] By virtue of decreasing congestion, transit use also saved 340 million gallons of gasoline; this cut carbon emissions by an additional three million metric tons. The overall effect of public transportation, therefore, is to diminish the United States' contribution to environmental degradation.

Despite these ostensible advantages, public transit in the United States faces many challenges. Public transportation generally flourishes in areas with high population densities, which is one reason why many European cities have successful transit networks. Because most American cities—with perhaps the exception of Boston, Chicago, New York City, Washington, D.C., and San Francisco—are largely decentralized, current public transit infrastructure often fails to meet consumers' cost criteria. Though an APTA study calculates that transit users on average save more than $9,596 per year by taking public transportation instead of driving, the typical citizen must account for all costs—implicit or explicit—when choosing to use public transit. Traveling time (perhaps the most important determinant), fare prices, fuel costs, as well as harder-to-measure factors, such as flexibility in movement and physical or mental

[1] "Public Transportation Response to Climate Change"

comfort, influence people's ridership decisions. Many transit networks lose out on riders, because their cities' sprawling structures cause consumers' implicit costs to exceed their explicit ones. Without major (and costly) infrastructure investments, American transit authorities cannot adequately serve their communities and, thus, rely on government subsidies to continue operations.

Nevertheless, public transit ridership in the United States has been on the rise since most networks were constructed in the 1960s and 1970s. Over the past three years 92 percent of transit operators in the United States have experienced increased ridership. In the second quarter of 2008, APTA reported that Americans took more than 2.8 billion trips on public transit vehicles, 1.5 million more trips each day than during the same time period in 2007. Though the exact reason behind this influx in riders remains unclear, 91 percent of transit operators attribute the change to rising fuel costs for auto drivers.[2] Many citizens have chosen to substitute the comfort and convenience of the car with the practicality of public transportation. If gas prices continue to rise, these trends may also persist, and the independent, car culture of America could shift to one that favors mass public transit. For this to occur, however, the United States would incur some heavy costs, including forgoing revenues from its formerly lucrative car industry, hiking fare prices for public transit systems currently hemorrhaging funds, and investing heavily in a new type of transportation infrastructure.

The United States' current economic and environmental situation mimics historical events. During the 1970s, political crises led to historically high oil prices, shocking the United States into reform of its oil-dependent economy. Economists of the

[2] The statistics in this paragraph come from a study conducted by the APTA.

time studied the costs and benefits of different types of transportation networks as part of this reform. Though their findings suggested the sustainability of public transit, American politicians continued to invest in highway and aviation systems, which at the time were politically more popular decisions. Americans today are traveling 250 percent more miles per capita each year and using over 36 percent more oil for transportation purposes than they did in 1973 as a result of decisions made in the 1970s.[3] In addition, in 1973, 52.3 percent of oil consumed in the United States was from transportation; it constitutes 68 percent today.[3]

Despite the lack of nationwide enthusiasm for transport sector reform in the 1970s, some local governments, using their own and state and federal funds, constructed transit networks in the United States' most populous cities. The Metropolitan Atlanta Rapid Transit Authority (MARTA) was formed in 1965, establishing its first bus route in 1972 and opening its first rail line in 1979. The bus lines were initially successful: in MARTA's inaugural year of operation, 65,543,400 passengers rode its buses, 11.5 million more people than rode on Atlanta's private bus company, the Atlanta Transit System (ATS), in 1971.[4] Policymakers attributed the success to MARTA's reduced fares; compared to 40 cents on the ATS, 15 cents earned a passenger a one way ticket on MARTA's bus lines throughout its entire service area of DeKalb and Fulton Counties.[4] MARTA's fare has increased gradually over time and is now \$1.75 for a one way ticket.

Funded mostly by federal money, a one percent sales tax in DeKalb and Fulton Counties, and other local subsidies, MARTA began rail operations for the first time on

[3] Statistics from the APTA Spring 2009 study, "Changing the Way America Moves"
[4] "History," MARTA website

June 30, 1979, on the East Line from Avondale to Georgia State Station. Despite the success of the bus network, MARTA policymakers chose to divert almost all bus lines to rail stations. This decision marked the beginning of MARTA's feeder service policy, which, by forcing passengers to ride both bus and rail systems to work, lengthened their commute times.

Though studies of MARTA at the time indicated the efficacy of its bus system over its rail lines, MARTA continued construction on its rail network into the 1980s and 1990s. Between 1979 and 2009, it set up several stations, which established two rail lines—one running East-West, the other North-South—and numerous bus routes throughout DeKalb and Fulton Counties. MARTA's attempts to expand beyond these two counties proved fruitless; suburbanites' fears that MARTA lines would draw poor—and though not explicitly stated, African American—customers to their safe, suburban neighborhoods prevented much of MARTA's growth and, as some argue, inhibited MARTA's ability to best serve Atlantans.

Nevertheless, throughout the course of MARTA's history, ridership has generally increased on both bus and rail networks, as demonstrated in Figures 1, 2, and 3. Ridership grew while the energy crisis loomed over American politics in the 1970s. During its bus-only years (from 1972-1979), MARTA saw a 39.2 percent increase in the number of boardings and a 37.6 percent increase in linked trips, which it accomplished by reducing real fares and increasing service miles (Kain, 1997). Ridership continued to rise in the mid 1980s as metro area employment burgeoned. It peaked during the economic boom of the late 1990s and the 1996 Summer Olympics, which the City of Atlanta hosted and for which it spent large sums of money on its public infrastructure in preparation for the Games. After 2001 patronage declined as employment rates also fell inside MARTA's service area. The effect was exacerbated by the fact that MARTA did not (and still does not) extend into Atlanta's rapidly growing suburban counties, which experienced greater employment levels than the Central Business District (CBD) or Downtown Atlanta.

Some transportation experts laud MARTA for its performance, pointing to its upward ridership trend and high safety rating as evidence of its accomplishments. In "Cost Effective Alternatives to Atlanta's Rail Rapid Transit System" (Kain, 1997), Harvard economist John F. Kain labels MARTA a success because it experienced large increases in use while ridership declined for transit systems across the nation. Others berate MARTA for its inefficiencies; they insist that if MARTA restructured its bus system to serve the larger metropolitan area, diverted funds from its rail network, and expanded into suburban Atlanta, it could produce much greater ridership numbers and cut back on both gas consumption and pollution (Brown and Thompson, 2008). They also point to the use of boarding numbers (the number of people boarding buses and trains) in economists' regressions as mistakenly leading people to believe that MARTA ridership has increased (Kain, 1997). This increase reflects only a change in transit policy: when MARTA decided to switch its bus system from a stand-alone network to a feeder network for rail rapid transit, people were forced to transfer from buses to trains, artificially inflating the number of unlinked trips and boardings recorded. The policy change consequently had overall negative effects, lengthening transit travel times by more than five percent (Kain, 1997).

Variation in MARTA ridership reflects changes in several factors. Population, income per capita, unemployment rates, and the racial composition of the city all play roles in determining the number of people taking public transit. Low unemployment rates and high income per capita indicate Atlanta's financial well-being and generally result in high ridership totals; when people have employment to commute to, they tend to use the public transportation infrastructure. Also, MARTA grants greater mobility to those without access to automobiles. African Americans, the elderly, the poor, the handicapped, and young people especially benefit from public provision of city-wide transportation (Baum-Snow and Kahn, 2005). Thus, when the percentage of members of traditionally marginalized groups swells, MARTA ridership increases.

Changing environmental conditions causing variations in weather across the globe also influence people's transit decisions, inciting them to stay home instead of going to work or traveling. MARTA ridership, therefore, fluctuates according to weather conditions, defined in this paper as precipitation levels and temperature. Though the connection among weather, ridership, and gas prices may seem tenuous, it is actually quite close. Climate differences—however minute they appear to be—affect the market for oil by occasionally disturbing oil drilling operations, inflating the prices countries must pay to obtain fuel. Thus, changes in weather contribute to vacillating gas prices, and both variables have an effect on a person's choice to use his/her automobile or to utilize public transportation.

MARTA ridership has generally followed the trends of rising and falling gas prices, shown in Figure 4a. As fuel costs diminish, ridership decreases; conversely, as gas prices rise, public transit use increases, measured by the number of unlinked trips on

MARTA's bus and rail networks. Many factors could explain the positive correlation between gas prices and ridership. A heightened awareness of pollution caused by automobile travel and a renewed concern with American oil dependency make the determination of these factors a germane topic to current events, mostly because public transportation provides one alternative—perhaps less environmentally wasteful and, in the long run, less costly—to automobile transit.

Determinants of public transit use will be discussed through my analysis of annual and daily data on MARTA ridership. Whereas many studies have described the effects of fare prices, service levels, population density, and land use to public transportation usage, this paper's contribution to the field of transportation studies is a detailed analysis of the impact of rising fuel costs on ridership of a specific metropolitan system, MARTA. The paper also includes a discussion of the effect of weather, income, and race on transit usage to explore alternate explanations for public transit ridership trends. Using data collected directly from MARTA on daily station entries and exits from July 2006 – December 2008 and information from several governmental and non-governmental organizations on ridership statistics for 20 cities' transit networks over five years, I ran time series and fixed effects regressions to find that rising gas prices have a significant and positive effect on public transit use. With the assistance of ArcMap, a Geographical Information Systems (GIS) program, I was also able to map the correlation between income and race—measured at the census block level during the 2000 Census—and rail ridership at each station on an annual basis. A geographical analysis of these relationships showed that MARTA primarily serves lower income people and African-Americans residing south of the city center.

I. LITERATURE REVIEW

Contemporary studies of public transportation focus their efforts on deciphering what factors matter to determining ridership levels, with the aim of determining how transit agencies can break even financially and best serve the communities that surround them. Conducted by economists and urban studies experts, most of this research measures what policymakers can control: the consequences of fare reductions and service increases on transit usage and the impact of urban decentralization on the number of people taking bus or rail transit. Studies find that reducing fare prices and increasing the number of buses and trains servicing customers have positive effects on ridership (Kain and Liu, 1999). A study entitled “Fare Elasticity and Its Application to Forecasting Transit Demand” details the results of APTA research employing the Autoregressive Integrated Moving Average (ARIMA) model to estimate fare elasticities. Using information from a special survey, which obtained ridership data 24 months before and after 52 transit systems raised their fare prices, the study concludes that on average, during all hours and in all cities, a ten percent increase in bus fares would result in a four percent decrease in ridership; i.e., the fare elasticity of public transit ridership is -0.40. It also finds that fare elasticities vary for bus systems in small versus large urbanized areas (categorized as fewer and greater than 1 million people, respectively) and during peak-hour and off peak-hour times. For example, peak-hour commuters are much less responsive to fare changes (their fare elasticity is -0.23) than transit passengers travelling during off-peak hours (whose fare elasticity is -0.42). APTA’s general result of -0.40 counters the previously-accepted Simpson-Curtin formula, which postulated a transit fare elasticity of -0.33 (i.e., a 10 percent increase in fare prices would result in a 3.3 percent decrease in transit patronage). Despite the difference in the supposed fare elasticities, though, the conclusions of the two studies remain the same: the act of raising fare prices decreases ridership levels in all cities, at all times.

Similarly, numerous studies show that lowering the number of a system's buses and trains in operation deters people from riding public transit. Many transit users cite faster commute times, minimized costs, and convenience (ease of use and physical proximity to transit stations) as incentives to take advantage of publicly-supplied transit networks. When policymakers reduce service, these incentives disappear, and as Baum-Snow and Kahn argue in their paper, "Effects of Urban Rail Transit Expansions" (Baum-Snow and Kahn, 2005), "if transit takes significantly longer than driving, it is only going to be used by the poor, because their low value of time makes them uniquely willing to avoid the fixed pecuniary cost of driving by taking transit." As service is cut, passengers "on the margin" (i.e., those who own cars and, therefore, are not financially or physically tied to utilizing public transportation) change their behavior to maximize the new set of options. Therefore, reducing service levels deters these discretionary passengers from consuming public transportation and acts to the detriment of those passengers without other transit options.

Demographic factors, such as population near the station, income, and employment levels, also influence public transit ridership, according to several transit experts. The absolute number of transit passengers rises as population increases. This result, however, may reflect the import of increased population density, rather than larger population size, to transit usage. Income has a similar effect on ridership; increasing income in an area indicates high employment rates, and because Americans typically ride public transit to work, higher income levels translate to a greater number of commuters than lower income levels do. Public transportation also has redistributive effects among people of different incomes; it empowers the poor, politically-marginalized, and disabled to be more mobile, especially when they have greater access to public buses (Baum-Snow and Kahn, 2005). Employment has a positive effect on transit usage, as well. As unemployment rates climb, the number of people who must use public transportation to travel to work falls. According to Dr. Richard Voith's 1994 journal article, "Fares, Service Levels, and Demographics," however, the "demographic changes important to ridership are induced by transportation policy." The determination of fare prices and service levels, or transportation policy, shapes the demographics of the population surrounding transit stations. Transportation policy thus emerges as perhaps the most important factor influencing people's decision to use public transit, though population, income, and employment affect ridership levels, as well.

Urban decentralization has also been demonstrated to have a significant impact on transit usage. Since World War II, Americans have extended the reach of their cities, moving residences, and eventually, jobs, from downtown centers to the suburbs. This residential and commercial decentralization generally works to the detriment of public transportation, especially rail transit, which best serves densely-populated, centralized cities. The article, "The Effects of Urban Spatial Structure on Travel Demand in the United States," (Bento et al., 1990) draws on data from households in 114 urban areas in a logit model to assess the impact of urban form and public transit supply on commute choices and annual vehicle miles traveled (VMT). It finds that the probability of driving to work becomes smaller as population centrality and rail miles supplied grow larger and as road density falls. Specifically, a 10 percent increase in population centrality lowers the chance that a worker drives to work by one percentage point and reduces the annual number of VMT by 1.5 percent.

A study conducted by Brown and Thompson, “The Relationship between Transit Ridership and Urban Decentralization: Insights from Atlanta” (2008), examines the relationship between transit ridership and decentralization in Atlanta, a major metropolitan area undergoing rapid growth in a short period of time. Utilizing data between 1978 and 2003 and controlling for fare prices, service levels, motor fuel costs, and income, their time-series analysis compares patterns of transit patronage over time with patterns of growth and decentralization of population and employment. They discover that employment growth outside the transit service area has a large and negative impact on transit ridership; that is, as businesses (but not necessarily residences) move out of the CBD and, therefore, out of MARTA’s network of buses and trains, Atlantans use MARTA less often than before. They explain this result by arguing that the distribution of employment is generally a good proxy for entertainment, shopping, personal business, and educational sites. Therefore, even passengers who ride MARTA for reasons other than commuting to work have fewer incentives to use MARTA when it does not connect to those sites. According to their assessment, MARTA should change its policies to reflect this decentralization, shifting funds from its rail service to its bus system. Policymakers have greater flexibility in altering the bus network, which generally costs less to fund than its counterpart, the ironically immobile rail system. MARTA, however, has yet to adopt Brown and Thompson’s multi-destination approach that promises to connect neighborhoods and provide transportation to decentralized employment locations.

Despite the large number of studies on the aforementioned topics, fewer academics have delved into the rapports between weather and transit use and gas prices and ridership. A professor of geography at the University of Illinois, Dr. Stanley A. Changnon in his paper, “Effects of summer precipitation on urban transportation,” (Changnon, 1995), found that on rainy days in Chicago, the public transit system experienced a 3-5 percent decrease in ridership, with most decreases occurring during midday. He predicted that a future climate with more summer rain days, somewhat higher rainfalls, and more storms would translate to decreased ridership on public transportation systems. This prediction assumes that environmental change will lead to higher temperatures and increased precipitation; however, even if this depiction of the future is physically manifested, the upward trend in public transport usage will likely remain unharmed as harsher weather conditions indirectly affect petroleum costs.

The lack of academic literature on the relationship between gas prices and ridership may stem from its political implications. Americans’ historic reliance on oil (both foreign and domestic), the United States’ complex diplomatic relations with other nations over the control of oil, and the recent obsession with environmental sustainability result in policymakers, not objective researchers, publishing most of the material on potential causalities or correlations between fuel costs and public transportation usage. Reports that academics have published on the effect of gas prices on ridership, however, mostly mimic the findings of such organizations. Brown and Thompson noted in their 2008 study of Atlanta transit that as the real price of fuel increases, transit ridership will grow. Baum-Snow and Kahn concurred: increases in gas prices, parking fees, and road congestion incentivize public transit.[5] These effects were demonstrated in a fixed effects regression on panel data, which controlled for changes in transit fares, citywide changes in transit quality, and changes in local economic conditions. The authors of the 1989 "Gasoline Consumption and Cities" disagree. According to their logic, land use and transportation infrastructure, not gas price or income variations, determine gasoline consumption; increasing urban density, strengthening cities' centers, providing good public transportation, and limiting the automobile infrastructure would constrict the use of fuel, undermining automobile independence and encouraging public transit use.

This paper provides an important perspective on the relationship between gas prices and transit ridership. Whereas other studies resort mainly to panel data and simple fixed effects regressions to ascertain correlation and causality, this report uses two types of data: panel data on public transit ridership collected annually from 20 cities, and time series data on station entries and exits from Atlanta amassed daily. Taken together, these diverse data sets permit the determination of the effect of rising and falling gas prices on public transportation usage with a greater certainty than possible with exclusively panel or time series data. This study also employs many different types of regressions. Previous papers on panel data—drawn from several different transit authorities across the United States and not, as mine does, from a particular transportation organization—include dummy and instrumental variables for population, income, and average commute times; some use even more esoteric regressions, such as the constant elasticity model and the Prais-Weinstein autoregression procedure, which corrects for first-order autocorrelated residuals. Though I also employ dummy variables for years, months, and

[5] "The Effects of New Public Projects to Expand Urban Rail Transit," 2000

days of the week, as well as for levels of precipitation and temperature, my fixed effects and OLS regressions are notable for their simplicity and easy interpretation. By addressing both annual and daily trends, the paper uniquely provides conclusions on short and long term behaviors.

II. DATA DESCRIPTION

1. *Daily*

To analyze the relationships between weather, gas prices, and MARTA ridership, I labeled the data set as a time series, creating dummy variables for days of the week and months of the year in each regression. The binary variables helped distinguish the effects of varying weather or vacillating gas prices on ridership during typical transit days (i.e., Monday through Friday in non-vacation months) from those on atypical transit days (i.e., the weekend during vacation months). Labeling months as dummy variables also accounted for the fact that precipitation and temperature vary according to month or season, especially in Atlanta's temperate climate.

In some regressions, I also generated dummy variables for different levels of precipitation and temperature. The difference between one millimeter of rain and two is small and perhaps insignificant, but 50 millimeters of rain, considered very heavy in Atlanta, is much, much larger and more impactful. Thus, the binary variables for "light," "moderate," and "heavy,"—or in the case of temperature, "cold" and "hot"—capture more accurately the effect of "unpopular" weather on MARTA station entries. Precipitation and temperature dummy variables were then combined into interaction variables to determine the effect of "crummy" weather on people's predilection for public transit. For example, “heavy” rain and “cold” weather on the same day may strongly encourage a passenger to choose to stay home from or drive to work, instead of riding public transit, whereas “light” rain and “hot” weather does not.

In 2006, MARTA installed new electronic systems in all of its stations, which recorded the total number of entries and exits into each station on an hourly basis. In this analysis, I use the information from these machines, aggregated to the daily level and amassed from July 2006 – December 2008, in time series regressions measuring the effect of weather variables (temperature and precipitation) and gas prices on the number of entries and exits into the MARTA stations. These figures (entries and exits into the station) are not always reflective of the total number of transit users, because the electronic counter’s location—at the entrance to the underground rail system—provides a good proxy only for MARTA’s rail riders; MARTA’s bus riders typically mount the bus at various stops throughout DeKalb and Fulton Counties or directly outside MARTA station buildings, bypassing the electric counters. The results of these regressions, therefore, explain primarily rail ridership trends, though bus ridership trends are likely closely related.

The variable “total entries” (or “total exits”) aggregates the total number of entries into (or exits from) every station each day. Figure 5 shows that the number of total entries has steadily increased over the twenty-seven month observation period, falling slightly in the latter months of 2008. The total number of entries and exits varies largely by time of day, day of the week, and month of the year, as demonstrated in Figures 6 and 7. Stations experience the greatest activity at normal commute times (around 9 a.m. and 5 p.m.) on weekdays during non-vacation months (essentially, every month besides

November, December, and January). This observation indicates the primary use of public transit in Atlanta: transportation to work. Whereas in European cities tourists also contribute in large part to ridership levels, in Atlanta inhabitants of the metro area seem the primary consumers of the public transit network.

Each MARTA station's location also contributes to its daily number of entries and exits. Stations in areas with greater residential and commercial density generally have a larger number of entries and exits, a finding consistent with policymakers' assertion that land use density has a positive relationship with public transit ridership. Additionally, stations located at MARTA's four terminus points (i.e., at the ends of the North/South and East/West lines) experience high ridership levels of greater than 4.1 million station entries per year. This phenomenon may occur because residents living far outside the CBD use MARTA to cut down on driving commute times or because those terminal stations serve a larger population, as they represent the last (or first) stops on the rail lines. Similarly, four of the five stations on MARTA's North line directly above and within a few miles of Five Points (the central rail station and the connection between East/West and North/South lines) experience high levels of ridership, most likely due to their location in Atlanta's CBD; employees leaving one of the many commercial buildings in Downtown or Midtown Atlanta enter into these stations as they commute home. Interestingly, racial and income breakdowns also seem correlated with MARTA rail ridership. As the percentage of the total population that is African American increases and as median household income lowers, the total number of station entries rises, especially in South Atlanta, where African American and/or lower income populations reside.

Information on daily gas prices was obtained from GasBuddy.com, an organization that collects average prices for "regular" gasoline in metropolitan areas across the United States and displays them on its Internet site for local consumers to find the best deals on gas. According to data from GasBuddy.com and Figure 8, gas prices in Atlanta have vacillated over the past two and a half years, reaching a low of $1.452 on Dec. 31, 2008, and a high of $4.131 on Sept. 16, 2008. Gas prices peaked in Atlanta in September 2008 when a hurricane disrupted the supply of oil from Texas to several southeastern states. During that ten day period, gas was either prohibitively expensive—in some places in Atlanta, it cost almost $5/gallon—or unavailable. Gas prices have decreased dramatically since that mini-crisis; however, relatively high gas prices prior to October 2008 and media reports on the import and urgency of finding alternative methods of transportation cause many to predict that gas prices will rise once again. Or they conjecture that, at the very least, consumer choice will mimic the response made during periods of high gas prices; i.e., automobile users will substitute public transit for commute by car.

The Global Observing Systems Information Center provided data on daily weather patterns from its post at Atlanta's Hartsfield-Jackson Airport. Precipitation levels (estimated in millimeters) and minimum and maximum temperatures (measured in degrees Fahrenheit) proved most pertinent to my investigation on how bad weather—defined as very rainy and/or very hot or cold—affected MARTA ridership. In general, Atlanta receives very little rain (in comparison to the rest of the world, that is), but when rain does fall, it tends to be moderately heavy. Atlanta's range of temperatures also reflects its temperate climate: the temperature rarely goes below 30 degrees Fahrenheit or above 100 degrees. Most would complain that Atlanta's humidity, not its precipitation or extreme temperatures, deters them from venturing outside.

To facilitate the interpretation of my regressions, I transformed the precipitation and temperature variables into dummy variables, classifying them as levels on a spectrum. After running regressions on their absolute values, I labeled "light rain" as daily precipitation of under 5 millimeters (or the bottom 50 percent of rainy days), "moderate rain" as between 5 and 14.5 millimeters (50 to 75th percentiles), and "heavy rain" as above 14.5 millimeters (the top 25 percent of days which experienced rain). Similarly, any temperature below 35.5 degrees Fahrenheit (the bottom 15 percent of observed temperatures) became "cold," and any temperature above 88.5 degrees Fahrenheit (the top 15 percent) was labeled "hot." I also generated interaction variables for the intensity of rainfall and cold or hot temperatures, accounting for very bad weather days, which may further induce people to substitute auto transportation for public transportation or to stay home.

2. *Annual*

Because my panel data set contained information on 20 different light rail transit systems during five years in the 2000s, I used transit system and time fixed effects regressions to estimate the effect of rising and falling gas prices (and other variables, such as per capita personal income, unemployment, and population) on the total number of unlinked trips for each city's network. The transit system fixed effects variable controlled for differences among stations attributable to their locations across the United States but invariant over time; thus, disparities in the size of the cities, local and state laws, the geographical extensiveness of the cities' transit networks, and those networks' service levels did not bias regression results, because the fixed effects variable recorded that bias. Time fixed effects (which the coefficients of year dummy variables captured in this regression) accounted for effects that varied across time for each station but were constant across all stations.

I found data on the annual number of unlinked trips for the twenty, most-used light rail transit networks across the United States from the American Public Transportation Association's 2008 Fact Book. The Fact Book reported each transit system's estimation of their total rail ridership in 2001, 2002, 2003, 2004, and 2006. Ridership grew across all light rail systems during this period, rising from a mean of 17,414,655 unlinked trips per city public transit network in 2001, to an average of 20,734,516 unlinked trips in 2006. The number of unlinked trips also grew for each transit system (shown in Figure 9), though their absolute values differed based on the city's population, location, and the service level of the transit network (see Figure 10 and Table 2). For example, Atlanta experienced much greater ridership than Buffalo, because its larger population caused a greater number of people to have access to the MARTA light rail system than would be the case in upstate New York.

GasBuddy.com provided the average annual gas prices for the twenty cities. On average and with the exception of the year 2002, gas prices rose across the nation, peaking in 2006 with a mean fuel cost of $2.59—a trend pictured in Figure 11.

I used other variables, including unemployment rates, per capita personal income, and population, in the fixed effects regression to control for omitted variable bias, sorting out the effect of gas prices on public transit usage from other variables known to influence it. The Bureau of Labor Statistics contained average annual unemployment rates on the level of Metropolitan Statistical Areas (MSA). Though the MSA often spans a larger area than that covered by the city's transit network, the data collected in the MSA serve as a good proxy for employment, population, and income trends for the smaller geographical area. The Bureau of Economic Analysis BEARFACTS included per capita personal income and population estimates for the MSA.

3. Geographic

Using ArcMap, a GIS computer program, I created a map to show the correlation between income and race in a census block group and ridership levels at the station within the block group. Shaded parts of the map represent rising income brackets and racial breakdowns in percentage terms, while graduated symbols on each station's location on the map signify the number of entries into that specific station and grow in size as the number of entries increases.

The Atlanta Regional Commission's website made available for download geographical overlays for metropolitan Atlanta's counties, road network, and MARTA bus and rail systems, which I used to create a base map of Atlanta. American FactFinder, a service of the U.S. Census Bureau, supplied information on race, household income, and population at the census block group level, collected during the 2000 full census. I juxtaposed this information with the number of daily entries at each station in 2008 (collapsed to the annual level) to determine the relationship between race, income, and ridership. To facilitate this juxtaposition, I created half-mile-radius buffers around stations to determine which census block groups were associated with which stations. I then ran regressions on the total number of entries (broken down by station) on the various block groups' demographic data; for example, entries into Five Points (the central

MARTA station) were regressed with the fraction of the population that is African American, the fraction of the population that is Caucasian, and the average median household income of the block groups encompassed by the half-mile-radius buffer around Five Points station. Presumably, certain stations reside in neighborhoods with predominantly one race or one income class of people represented; a comparison elucidates the connection (if any) of these two variables to determining transit ridership.

Figure 12 shows MARTA's bus and rail networks and the way in which policymakers have chosen to distribute lines throughout DeKalb and Fulton Counties. Drawn directly from the MARTA website, Figure 13 focuses exclusively on MARTA's rail networks, and names of the stations are listed beside the stations themselves.

III. ANALYSIS

1. *Daily*

A. Gas prices

OLS regressions of gas prices, day dummy variables, and month dummy variables on the total number of entries into MARTA stations reveal the effect of gas prices on ridership when day and month effects are held constant. According to regressions (1)-(4), increases in gas prices have a positive and significant effect on daily ridership. Furthermore, fuel costs are likely to have an extensive margin effect on public transit use; that is, rising fuel costs entice new riders to begin utilizing MARTA. Thus, the total number of people riding MARTA, as well as the total number of station entries, increases as fuel becomes unaffordable to the average consumer. Numerically, the regression results show that when gas prices increase by one percent, the number of total entries rises by 0.2821 percent. Or, as fuel costs rise by US$1, the daily number of total entries into all MARTA stations swells by approximately 18,824. Table 3 details coefficients and t-statistics for each of the variables used in the regressions; certain variables were dropped to avoid perfect multicollinearity.

$$Total\ entries \equiv \beta_0 + \beta_1 gasprice \tag{1}$$

$$Log(total\ entries) = \beta_0 + \beta_1 \log(gasprice) \tag{2}$$

$$Log(total\ entries) = \beta_0 + \beta_1 gasprice \tag{3}$$

$$Total\ entries = \beta_0 + \beta_1 \log(gasprice) \tag{4}$$

Considering that the standard deviation of total entries over the 27-month period is 48,936.75, the effect of gas prices on total entries is somewhat substantial, though not overwhelming proof that fuel costs greatly impact passengers' decisions to ride MARTA rail. It is evident that fuel costs, at the very least, are related to MARTA rail ridership, but one could argue that gas prices are correlated to other factors that may affect ridership, and, therefore, omitted variable bias plagues the regression results. For example, federal policymakers may use income, another determinant of transit ridership, as a basis for setting tax levels on fuel, mitigating the effect of volatile world market prices for oil by stabilizing those costs on a local level. Rising and falling gas prices may also encourage MARTA policymakers to increase service levels, putting more trains and buses into circulation in anticipation of an influx in riders—efforts already shown to have a positive impact on ridership. In these scenarios, the regressions suffer from reverse causality, which, again, could bias their results. Nevertheless, gas prices are likely exogenous to this model, as they are largely determined on a global level, rather than by national or local entities, so the causal explanation of rising gas prices and increased ridership generally holds true. Running other regressions on the effect of gas prices on the total number of entries also disproves these queries, because the positive and significant relationship between the two variables persists.

Rising gas prices have a positive and significant effect on the total number of entries into MARTA stations on every day of the week, as demonstrated by a regression of gas prices and month and day dummy variables on the total number of entries. The effect becomes more pronounced on week days and smaller on Saturdays and Sundays, recorded in Table 4; however, the small effect of fuel costs on ridership levels on the weekend seems only to indicate the lower number of riders during off-peak days. On the weekdays, a $1 increase in the cost of fuel results in approximately half a standard deviation, or 24,000, more entries into MARTA stations, indicating that rising fuel costs incentivize public transit use for commuters. Following from these results, I conclude that there probably exist different elasticities for work week and weekend days with respect to gas prices, because people using MARTA on the weekends likely have no access to cars and, thus, ride MARTA without regard to alternatives or the rising or falling price of gas. Weekday commuters perhaps have greater sensitivities to gas prices, because they must commute to work and, therefore, are willing to choose whichever transit option costs less—both implicitly and explicitly.

Similarly, a regression of gas prices and day dummy variables on the total number of entries into all stations by month reveals a positive and significant effect for ten of the twelve months, indicated in Table 5. From July to October, the effect of rising gas prices on ridership is surprisingly prominent; in these cases, a $1 increase in the price of fuel results in ridership increasing by more than half a standard deviation each day. This trend could stem from the fact that these are typically warmer, non-rainy months and, thus, people are not deterred from riding MARTA.

Given that all regressions run on the effect of gas prices on total entries into MARTA stations result in statistically significant and positive coefficients, I conclude that fuel costs do, indeed, play a role in determining people's transit decisions. Ridership rises as gas prices increase, and though the short term effect of higher gas prices on station entries is small (at most, the number of entries rises by 25,186 for every $1 increase in the cost of gas), there is no evidence that its long term effect would not be much larger. A lag period may be necessary for people to shift their mode of transportation from automobiles to public transit in response to gas prices. Because this set of data covers 27 months (of which only the latter third experienced abnormally high fuel costs), it may not capture the lag effect of rising gas prices and, thus, fails to indicate their true impact on ridership. Further studies of MARTA ridership would do well to examine a longer period of daily data than this report was able to, in order to fully assess the importance of fuel costs to the total number of station entries.

There may also exist an absolute gas price at which people decide that transportation by automobile is too costly to continue. In that scenario, they may choose to utilize public transit, the potentially more individually cost-efficient option (though total market efficiency is still debatable). That absolute gas price was not reached in Atlanta between July 2006 and December 2008; otherwise, the regression coefficients on the variable for fuel costs would have been much higher. This price, therefore, must be above $4.13, the highest gas price recorded during that period.

B. Weather

A regression of precipitation, temperature, and day and month dummy variables on the total number of entries reveals the effects of weather on transit ridership. This relationship may become increasingly important as climate change impacts the warmth (or coldness) and dryness (or wetness) of different parts of the world, inadvertently influencing people's day-to-day decisions, including the type of transit they choose. According to the results of equation (5), an increase in the amount of precipitation on any given day in Atlanta by one millimeter leads to a decline in transit ridership of approximately 292 entries.

$$Total\ entries = \beta_0 + \beta_1 precipitation + \beta_2 mintemperature + \beta_3 maxtemperature \tag{5}$$

This effect seems small, especially because the average number of total entries into MARTA stations per day is approximately 165,000. However, as the amount of precipitation increases, so does its effect on ridership: heavy rain deters people far more from entering MARTA stations than light rain does. When precipitation equals 14.5 millimeters or more, the number of total entries into MARTA stations decreases by almost one standard deviation from the average number of total entries on any given day. This is most likely an intensive margin effect, rather than an extensive one; heavy rain deters people already using MARTA from riding it on that day, in contrast to good weather enticing new riders to the system.

Though the regression results of precipitation on total entries may be statistically significant, the rarity of rain in Atlanta's climate makes their importance debatable. From July 2006 to December 2008, 73.3 percent of the days in Atlanta were precipitation-free. On days Atlanta did experience rain, 50 percent of the time precipitation was less than 5 millimeters; 25 percent of the time it was greater than 14.5 millimeters.

Nevertheless, this finding is consistent with Changnon's results in Chicago, discussed in the literature review of this paper. Changnon found that public transit ridership decreased by three-five percent on heavily rainy days (defined by the author as >12.8 millimeters of precipitation). In Atlanta, when precipitation exceeds 14.5 millimeters (my definition of "heavy rain"), ridership falls by approximately 2.6 percent. The slight difference in effects is somewhat surprising: one would postulate that ridership in Chicago was less elastic than that of Atlanta, especially given Chicago's extensive rail network and high transit usage rates. However, many Atlantans using MARTA may not have access to cars and, therefore, cannot substitute automobile travel for commuting by public transit during bad weather. The average rider on Chicago's transit lines, on the other hand, most likely has a large enough income to afford a car, trading in public transit for its comfier alternative on rainy days.

Temperature plays a far smaller role in the determination of MARTA ridership than precipitation does. In equation (5), the variable, "Max temperature," is statistically significant at the 5 and 10 percent levels and, curiously, has a positive coefficient; that is, as temperature rises by one degree Fahrenheit, the total number of entries increases by approximately 396. Despite its statistical significance, this effect is small enough to discount or to explain by suggesting omitted variable bias.

Removing temperature variables from regression (5) reveals similar and significant results for the impact of precipitation on ridership; similarly, eliminating the precipitation variable from the first regression shows that both minimum temperature (how cold it gets) and maximum temperature (how hot it can be) are statistically significant but, in actuality, have small effects on deterring passengers from riding MARTA.

The use of dummy variables for different levels of precipitation and varying degrees of hot and cold proved helpful to my analysis on the effect of weather on ridership, because it delineated very hot, cold, or rainy days from ones with more temperate weather. Days with “light” rain were defined by having precipitation levels greater than zero millimeters and less than five millimeters; “moderate” precipitation ranges between five and 14.5 millimeters, and “heavy” rain was greater than 14.5 millimeters. “Cold” temperatures constituted 15 percent of the observations and were defined as being below 35.5 degrees Fahrenheit; “hot” temperatures composed the top 15 percent of observations.

Interestingly but not surprisingly, rain proved a greater deterrent to public transit use than temperature did. Days of “heavy” rain saw decreases in ridership of about 11,000 entries. Though, again, this was not a physically significant result, because the average number of total entries approaches 165,000 each day. Dropping either precipitation or temperature dummies from regression (6) produced similar results and, thus, was not included in Table 10, which displays results from all regressions run on the relationship between weather and ridership.

$$Total\ entries = \beta_0 + \beta_1 light + \beta_2 moderate + \beta_3 heavy + \beta_4 cold + \beta_5 hot \quad (6)$$

Interaction variables were added in regression (7) to assess the effect of particularly bad weather on MARTA ridership. The three levels of "crummy" weather represented interactions of the dummy variable for "cold" temperatures with "light," "moderate," and "heavy" precipitation dummies ("crummy," "crummier," and "crummiest," respectively). The three levels of "sucky" weather demonstrated interactions between the dummy variable for "hot" temperatures and the precipitation dummy variables ("sucky"=light*hot; "suckier"=moderate*hot; and "suckiest"=heavy*hot). As evidenced from Table 6, only the coefficient for "crummiest" weather was significant. Its decidedly negative effect on the total number of station entries demonstrates Atlantans' reluctance to use public transit during bouts of cold and heavily rainy weather; on days with the "crummiest" weather, total entries fall by approximately 36,360. This result could be explained in two ways: when there is extremely bad weather, typical transit users either stay home (and presumably, miss work) or the so-called discretionary riders (who own cars) decide to commute by automobile, rather than waiting at the cold, rainy station for a train. A test of joint significance on the bad weather variables results in an F-statistic of 29.02, indicating that these interaction variables are, indeed, jointly significant.

$$Total\ entries = \beta_0 + \beta_1 crummy + \beta_2 crummier + \beta_3 crummiest + \beta_4 sucky + \beta_5 suckier + \beta_6 suckiest \quad (7)$$

2. Annual

An OLS regression on the effect of gas prices, unemployment rates, income, population, and year dummies on the number of unlinked trips in 20 cities across a five-year period yields statistically significant coefficients on unemployment and population variables. These factors were included in the regression, because literature on the subject of transportations studies suggests they are important to determining ridership levels. Despite their general importance to transit ridership, fare prices were not included. The lack of variation in base fare prices across cities' transit systems makes them a non-factor in determining effects of various factors on ridership with panel data, because a one-way ticket generally runs between \$1.50 and \$2.50, depending on the popularity of the transit system.

$$Unlinked\ trips = \beta_0 + \beta_1 gasprice + \beta_2 unemployment + \beta_3 income + \beta_4 population \quad (8)$$

$$Log(unlinked\ trips) = \beta_0 + \beta_1 \log(gasprice) + \beta_2 \log(unemployment) + \beta_3 \log(income) + \beta_4 \log(population) \quad (9)$$

The results of regression (8)—displayed in Table 7—imply that when unemployment rates rise by one percent, the number of unlinked trips decreases by approximately 664,820 per year. Considering that the mean number of trips per year (during the five year period) is 18,071,500, with a standard deviation of 20,233,640, the impact of rising unemployment rates on ridership is small; an increase in one percent of the unemployment rate leads to a decrease in the total number of unlinked trips by approximately 2.36 percent. The mean annual number of trips per station is large, because the transit systems themselves vary in size and scope—differences not accounted for in the regression output, which treats all networks equally; for example, MARTA receives many more riders per year than a similar transit network in Buffalo, NY, simply due to the population differences between the two cities. The unemployment-ridership trend most likely occurs because higher unemployment rates connote fewer people commuting to work and, thus, fewer people using public transit as a means of transportation to their places of employment. The effect is small, because not all recently-unemployed people used light rail in the past to commute; some may have ridden the bus or commuted by car. Therefore, unemployment of these people—the non-light rail users—does not contribute to the effect of rising unemployment rates on public transit ridership.

Changes in population have a larger, more statistically significant effect on transit ridership than unemployment rates do. When the population of the city increases by 100,000 people, the number of unlinked trips rises by 102,400,000, or in percentage terms, a ten percent increase in population leads to a 7.39 percent increase in ridership. This result could reflect a correlative or causal relationship. If correlative, a larger population would have a greater number of unlinked trips simply because more people lived within the transit system's bounds. If causal, the rising population would cause increased ridership, as more people chose or were forced to live near transit stations, congestion worsened due to the greater number of people working/living in the city, and population density (presumably) increased. The answer is likely the latter of the two explanations, thus validating the regression results.

Gas prices are curiously not significant in the regression. Furthermore, the variable's negative coefficient is inconsistent with earlier findings of rising gas prices leading to increased ridership. The coefficient is likely insignificant and negative because gas prices follow the same, upward trend across states and over time. There is, thus, not a large enough difference in prices to show an effect based on either state or time, especially given the short nature (five years) of the time period.

A transit system and time fixed effects regression (10) on the same variables produced statistically insignificant results. Regression (10) should have corrected for any differences in ridership based merely on the varying transit systems, as well as for differences over time that were constant for every transit network (system fixed effects symbolized by α, time effects by λ); however, because the trends for gas prices, unemployment, income, and population were the same across all cities, there was not enough differentiation to show city or time effects. For example, with the exception of the year 2002, average gas prices rose in all cities—but by only a small amount. Other studies may wish to compare data from American cities with those from European cities, where fuel costs are generally higher and vary more by country. This type of study would provide differences in data great enough to demonstrate the true effect of gas prices and demographic information on transit ridership, and a fixed effects regression on that set of data would account for effects varying across countries but fixed over time, as well as effects varying across time but fixed for all countries (i.e., rising and falling costs of oil on the global market for petroleum).

$$Unlinked\ trips = \beta_0 + \beta_1(gas) + \beta_2(unemp\ rate) + \beta_3(income) + \alpha_i + \lambda_t \qquad (10)$$

3. Geographic

A geographical analysis of transit ridership revealed many interesting—and sometimes surprising—effects of demographic characteristics on MARTA usage. Transit ridership statistics used in the maps are the number of total entries per day by station in

2008 aggregated to the annual level. The use of total entries as the dependent variable could elicit empirical concerns, as it fails to capture whether the station is the origin or destination of the rider and, thus, whether the station's surrounding area is residential (riders would enter this station in the morning and exit at night) or commercial (conversely, riders would exit this station in the morning and enter at night). Recorded by the 2000 Census, aggregated or average block group demographic statistics in DeKalb and Fulton Counties, therefore, might not match the demographics of the MARTA rider pool; i.e., MARTA's users may not be the ones living near the stations, but perhaps just working near them. Thus, one must be careful with reading too far into the results of this regression, because income and race statistics from a neighboring block group to the station may not reflect their ridership patterns. However, despite the difference in years that the two sets of data were collected, they can still be compared, because trends in Atlanta's demographic makeup—the location of high income versus low income residents, etc.—have not changed significantly during the elapsed eight-year time period, and the variable "station entries," nevertheless, accounts for some relationship between surrounding areas' demographics and MARTA ridership.

Perhaps the least surprising result of this geographical analysis is that MARTA generally runs through and serves areas of lower median household income (with the exception of MARTA's northbound line). As pictured in Figure 14, the median household income in south, southwest, and west Atlanta, for example, is mostly below $53,750; near MARTA lines, the median drops down to below $33,000. Though transit stations are reputed to encourage economic development, it appears that this has not been the case in these parts of Atlanta or that, at least, the economic development around the stations has not benefited their surrounding residents. However, this statement becomes less decisive when one ponders the alternative. No information is available regarding neighborhood income levels if/where stations had not been built; therefore, it becomes difficult to discern the true effect of stations' constructions on surrounding areas. Ridership in south, southwest, and west Atlanta, nevertheless, remains high, because Atlantans living there may not have the resources to afford automobiles or find that using MARTA cuts down on costs. Graduated symbols at each station are consistent with greater numbers of station entries on the southbound and westbound lines than on the northbound and eastbound lines.

However, an empirical analysis of this result—that income and ridership are correlated—proves the relationship insignificant. OLS regressions of the average median household income in 2000 (the log of median HH income) of block groups included in the station's buffer on the number of total entries in 2008 (the log of total entries) per station had no significant coefficients, despite the relationship visible on the map. This result contradicts other studies' findings, which conclude that the relationship between income and ridership is positive and significant. Taking only this study into consideration, it is, therefore, difficult to draw conclusions about the effect of income on ridership or to determine whether it is negative or positive, because empirical and physical analyses oppose each other. The relationship becomes increasingly intricate when one contemplates the fact that MARTA policymakers may have chosen to construct rail networks through poorer neighborhoods to ameliorate their transit options; therefore, any analysis of income and ridership may overstate the correlation, because policymakers intervened to make public transit available to low income Atlantans. Or, conversely, policymakers may have forced the construction of rail transit networks upon lower income neighborhoods, because their residents were less likely to protest the intrusion than people in higher income neighborhoods. In this case, the relationship would be similarly overstated but for strikingly distinct reasons.

Future studies on the subject, therefore, may benefit by including in the regressions the median household incomes of block groups with no MARTA access (i.e., residences too far from MARTA stations to walk or bike comfortably—due to busy roads, lack of sidewalks, etc.) and the median household incomes of block groups surrounding stations with no recorded entries (though this statistic would be difficult to find, as all MARTA stations recorded some number of daily entries). The addition of these two variables to the regressions may recover significant coefficients, because they serve as controls and, therefore, would prove some type of relationship between income and ridership. Further analyses may also wish to employ a dependent variable besides station entries—perhaps one that considers whether the statistic represents the origin or destination of the rider, which could be obtained through network surveys.

According to Figure 15, areas of low median household income generally exist in block groups with high percentages of African Americans, and stations in these low-income, largely African-American neighborhoods have high levels of ridership. This observation may result from the fact that MARTA rail lines generally run through census block groups with high percentages of African Americans; the stations are thus easily accessible to residents, who are more likely to use MARTA due to its proximity, rather than because African Americans use MARTA more than other racial or ethnic groups in Atlanta do.

Again, an empirical analysis of the relationship between race and ridership has insignificant results. OLS regressions of the percentage of black and the percentage of white residents in block groups surrounding a station on the number of entries per station result in only marginally significant coefficients at the 10 percent level. A test of joint significance on race percentage variables yields a low F-statistic (1.38), indicating that race—at least, in this analysis—is not a significant determinant of ridership. However, previous literature, as well as my own physical observations, suggests that there is a relationship between race, income, and ridership that, unfortunately, cannot be discerned with this specific set of data. Future studies on this subject would do well to include more data points to increase the number of degrees of freedom in the regressions.

IV. CONCLUSION

Based on regression results of time series and panel data on the effect of rising and falling fuel costs on public transit ridership, I find that gas prices do, indeed, have a positive and significant effect on the number of transit rail users. OLS regressions of Atlanta-area gas prices on the total number of MARTA station entries—collected on a daily basis—yield a statistically-significant coefficient of 18,824; that is, as fuel costs rise by $1, the daily number of total entries into all MARTA stations swells by approximately 18,824. Though seemingly small given the average number of station entries per day (approximately 165,000), this number nevertheless signifies an important relationship between the two variables—a relationship which may grow as gas prices rise beyond their current levels, inducing new riders to take to MARTA as auto transit becomes unaffordable to the average Atlantan. Similarly, a regression of weather measures (precipitation and temperature) on daily entries evidences the small but significant effect of poor weather conditions in deterring transit ridership. While perhaps not surprising, these results are important, because just as climate change affect global weather conditions, it will impact people's everyday lives, influencing their transit decisions by raising explicit and implicit costs (gasoline prices and the comfort of auto travel, for example) of different types of transportation.

Though OLS and fixed effects regressions of gas prices on ridership panel data revealed little as to correlation between the two variables, they produced some interesting results about the relationships between ridership, unemployment, and population. Regression results, accounting for differences among stations related to city size, network extensiveness, and transit service levels, showed that unemployment and ridership were negatively correlated, while population and the number of unlinked trips were positively related; these results mimic earlier findings from other economists and transit experts and reflect general knowledge that transit users living in dense cities in the United States utilize public transit primarily for commuting to work.

A geographic analysis of MARTA's rail network and stations demonstrated tentative links between ridership, race, and income. According to a visual analysis of these relationships, areas south of the city center—inhabited primarily by African Americans and residents with a median household income below $53,000—experience higher levels of ridership than North and East Atlanta. Empirical regressions of race and income on ridership, however, had insignificant results; it was thus difficult to discern whether these relationships were causal or correlated and if causal, the direction of the relationship. The nature of the data, especially the inability to distinguish whether stations were origins or destinations and whether surrounding areas were commercially or residentially developed, also called into question some of the results. In Atlanta (where these results may exclusively apply), race, income, and politics are inextricably intertwined. Therefore, any relation drawn from the three variables must include several caveats, the most important being that policymakers may have chosen (for beneficent or maleficent reasons—or perhaps both) to construct MARTA through lower-income, largely African American neighborhoods, thus artificially inflating the number of people from those demographic groups riding MARTA rail systems. Conversely, residents of higher income, largely Caucasian areas may not have ready access to MARTA stations and, therefore, overwhelmingly use cars to travel. Despite these caveats, it seems clear that demographics—especially unemployment rates, race, income, and population—partly impact MARTA ridership, in addition to the effect gas prices have on the number of station entries and unlinked trips.

The primary objective of this paper was to determine whether rising fuel costs caused increased use of public transit in Atlanta. While in other, denser cities (particularly those in Western Europe or Japan, which have both higher densities and perhaps more rapidly increasing fuel costs), rising gas prices may encourage auto users to switch to public transportation, in Atlanta this seems to be only part of the case, perhaps due in part to measurement error in collecting statistics on gas prices and other variables. Explaining this anomaly is surprisingly easy, when one considers that in Atlanta the culture of the car is all-encompassing. Huge highways, suburban residential sprawl, commercial decentralization, and a limited public transit infrastructure force inhabitants to rely on their automobiles for the most rapid form of transportation (though anyone stuck in Friday afternoon traffic on I-85 may refute that claim). However, the major questions facing not only Atlanta policymakers, but also national policymakers, are, is this type of automobile transportation sustainable environmentally and financially, and if not, how do we change it? Public transit may furnish a better, longer-lasting, and ultimately quality-of-life improving option to the American public, but further studies on MARTA and other transit networks must assess the environmental impacts of car transit versus public transportation, as well as calculate how much money the economy would gain (if any at all) if Americans switched to bus and train transit, in order to ascertain the best solution to both short term and long term transit problems.

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VI. APPENDICES

Figure 1: Bus Ridership Trends in Atlanta, 1972-2007

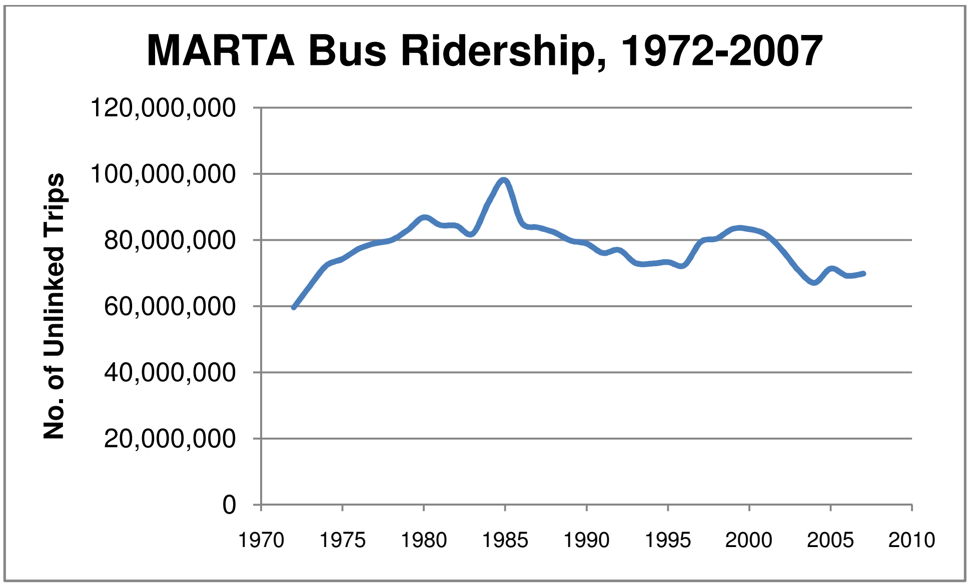


Figure 2: Rail Ridership Trends in Atlanta, 1979-2007

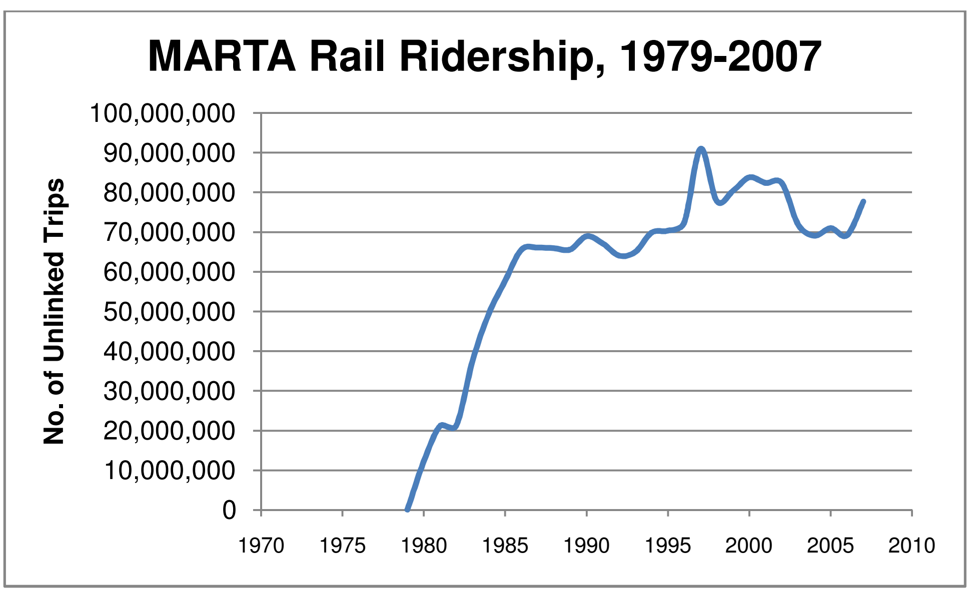


Figure 3: Fraction of Bus Ridership/Total Ridership, 1972-2007

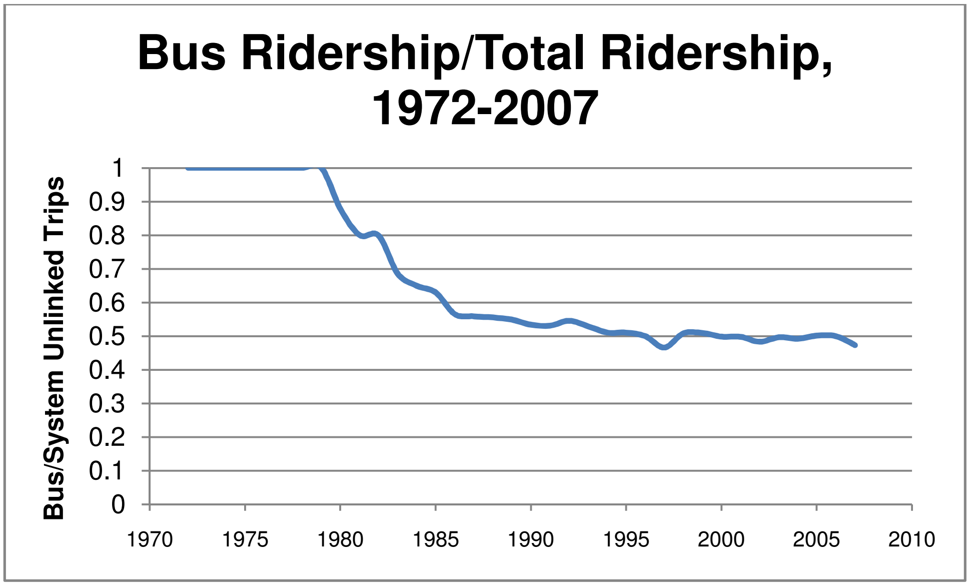
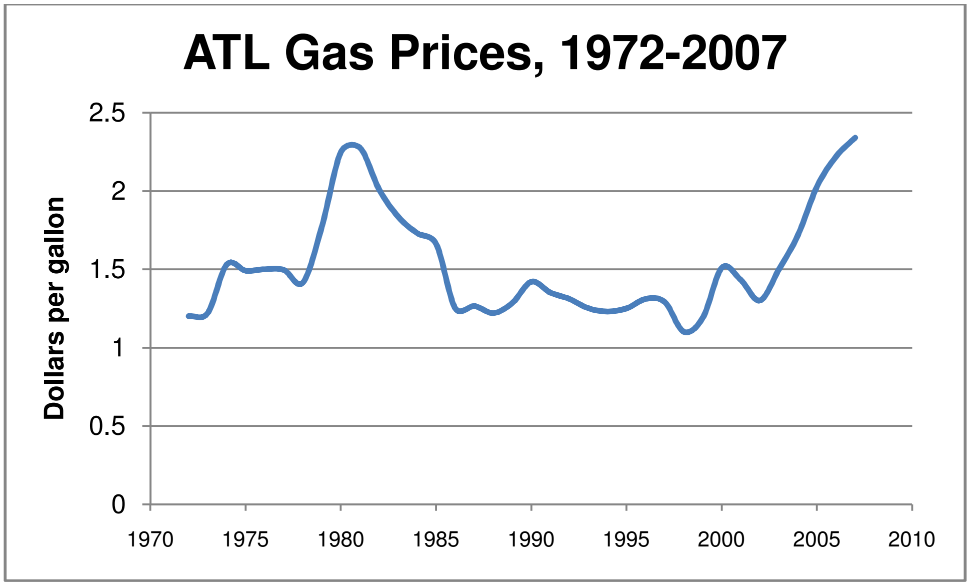
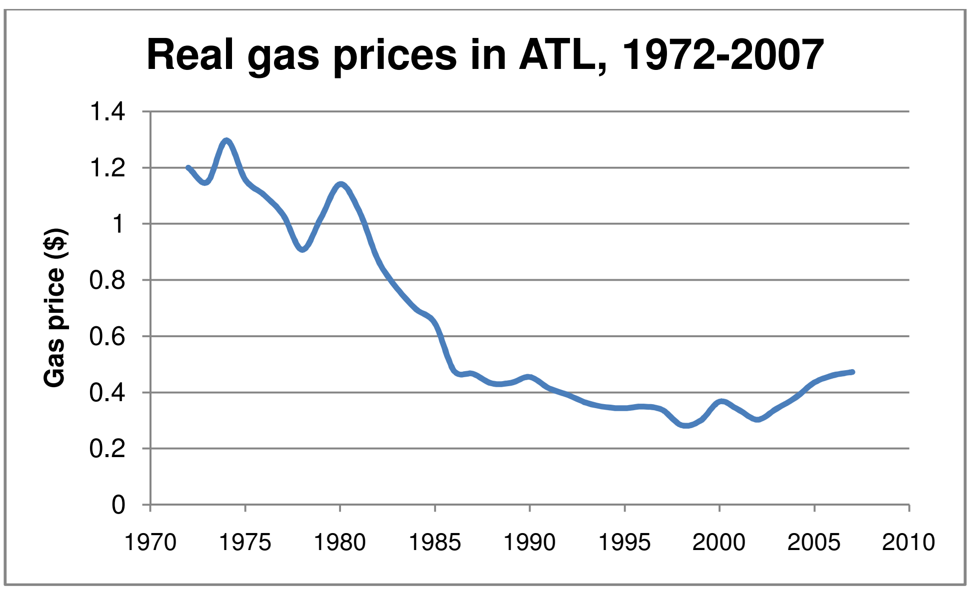


Figure 4a: Average Gas Prices in Atlanta, 1972-2007



NOTE: Gas prices are not adjusted for inflation.

Figure 4b: Real Gas Prices in Atlanta, 1972-2007



NOTE: The base year Consumer Price Index (CPI) in this figure is from 2000.

Figure 5: Trend of Total Station Entries, July 2006 – December 2008

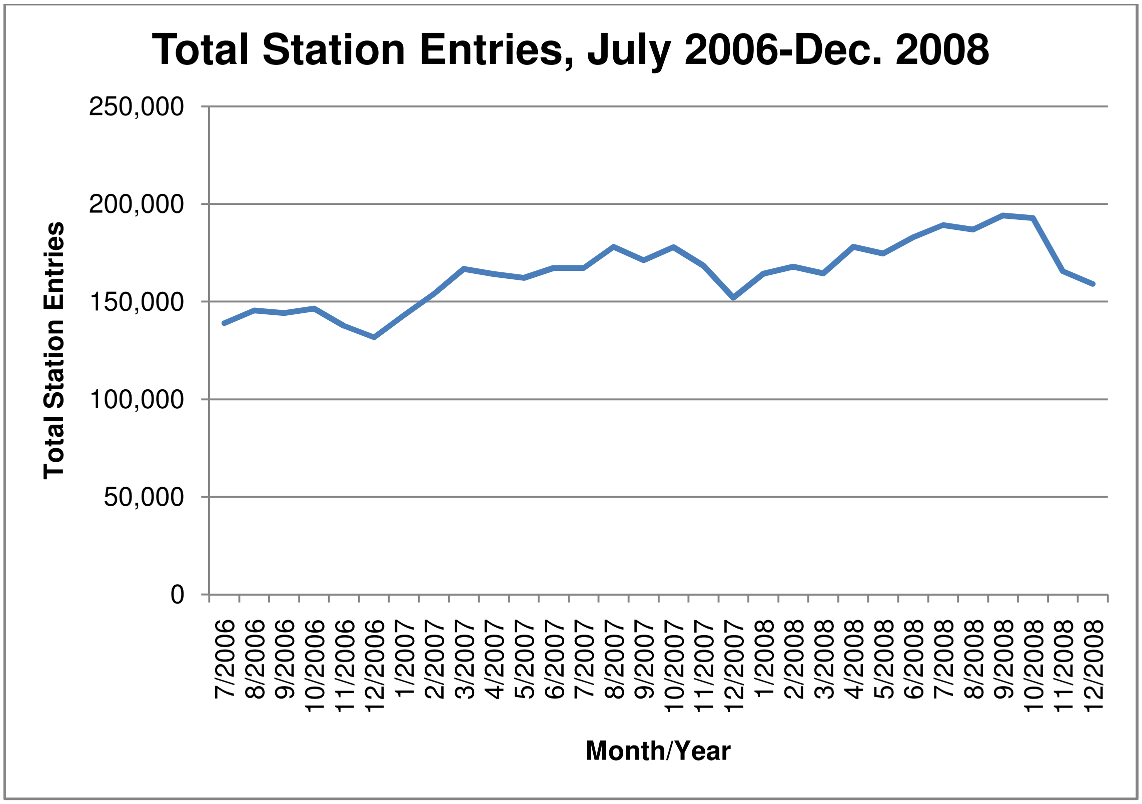


Figure 6: Average Total Entries Depending on Day of Week

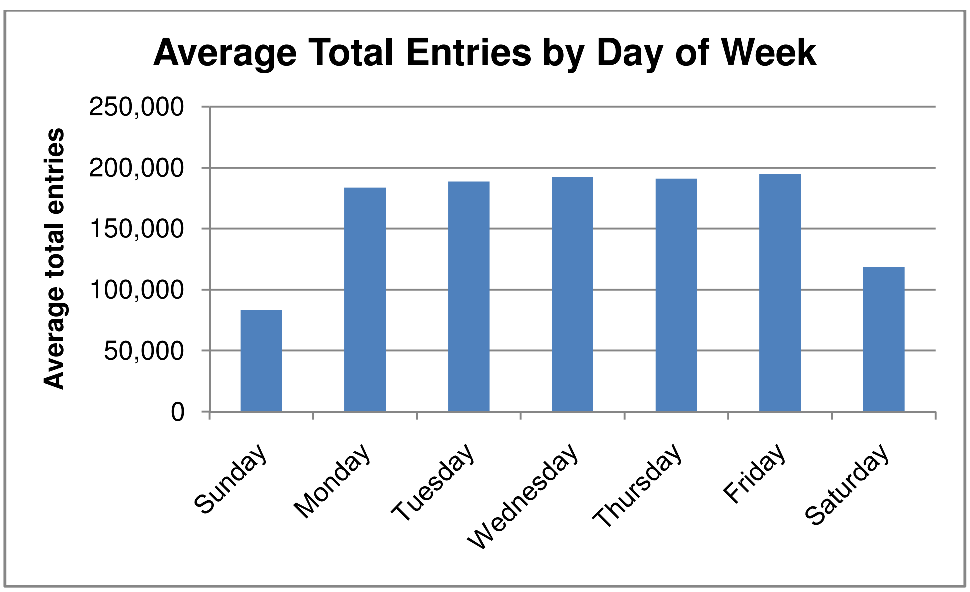


Figure 7: Average Total Entries by Month of Year

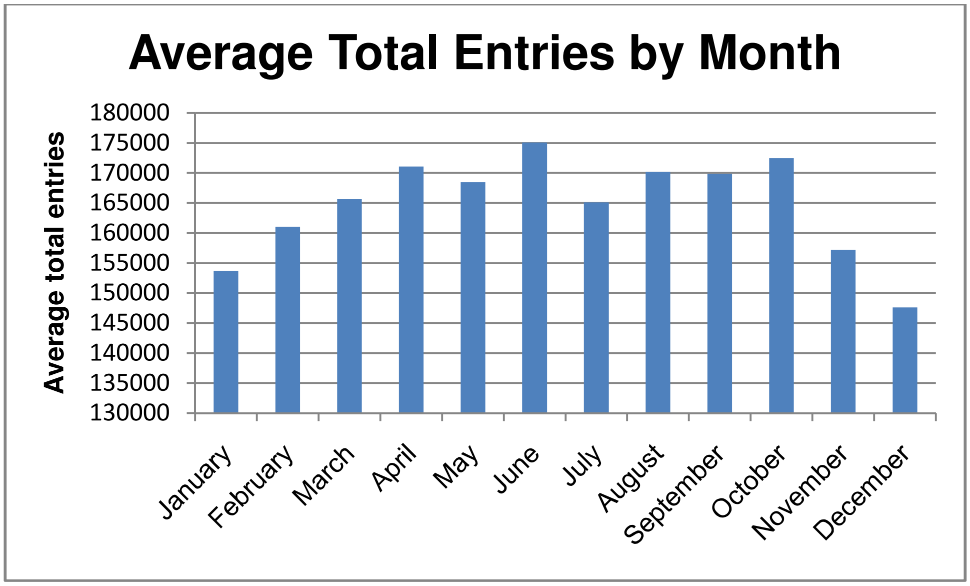


Table 1: Summary Statistics for Daily Data from July 2006-December 2008

Variable	Observations	Mean	Std. Dev.	Min	Max
Total entries	915	164,569	48,936.8	34,093	246,786
Gas prices	915	2.83108	0.643219	1.452	4.131
Precipitation (millimeters)	915	2.69607	7.924654	0.00	94.50
Temperature (minimum, ºF)	915	54.4489	15.19265	15.08	82.04
Temperature (maximum, ºF)	915	73.7675	14.77373	30.02	104

Figure 8: Average Daily Gas Prices in Atlanta, July 2006 – December 2008

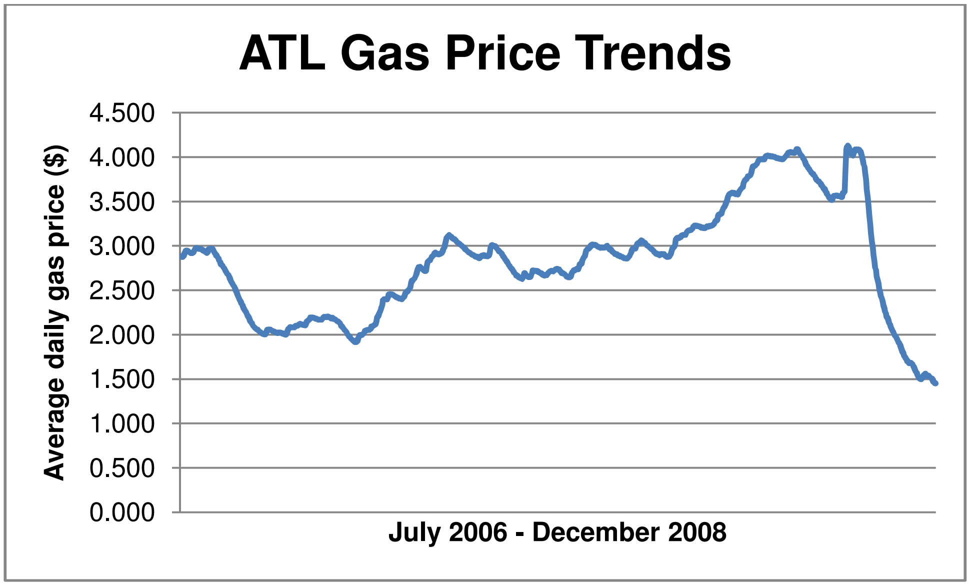


Figure 9: Trend of Average Unlinked Trips across All Transit Networks from 2001-2006

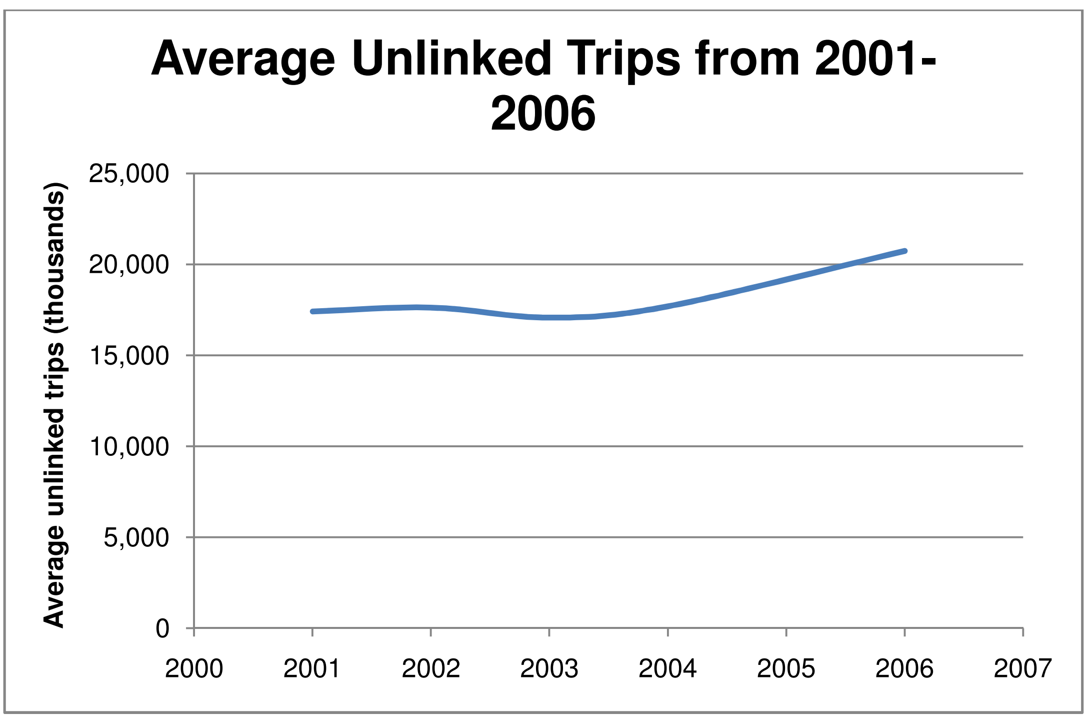
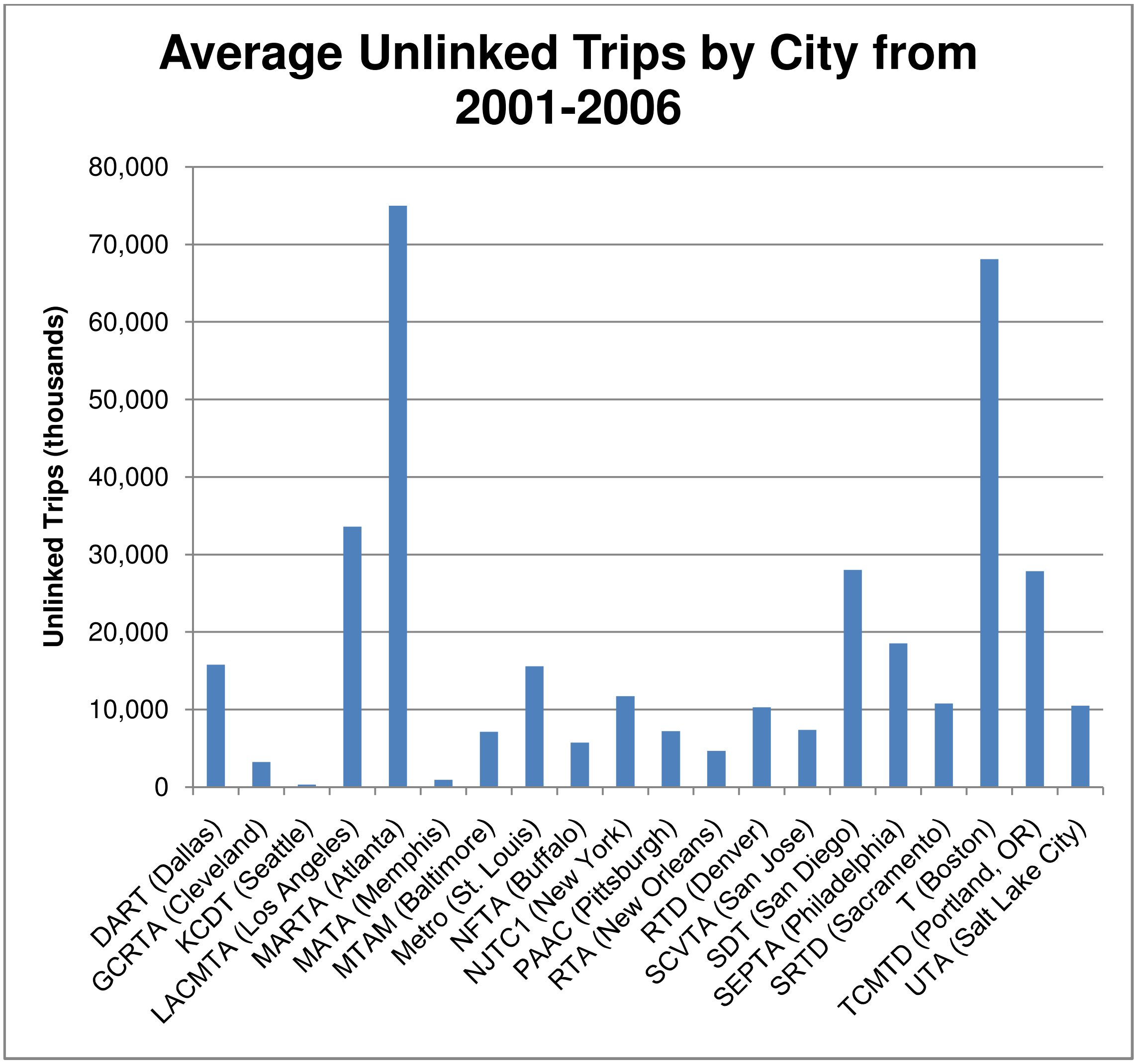


Figure 10: Average Unlinked Trips by Transit Network from 2001-2006



NOTE: The New Jersey Transit Corporation (NJTC) has a low number of unlinked trips, because it is one of several transit providers in the New York City area and, thus, does not represent all transit ridership in the city.

Table 2: Summary of Dependent, Independent Variables by City over Five-year Period

City	Unlinked trips (000s)		Gas		Unemployment	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Atlanta	74,977.2	6,833.60	1.580	0.5326	4.50	0.524
Baltimore	7,132.84	1,513.26	1.713	.510354	4.50	0.346
Boston	68,100.3	8,074.77	1.752	.4883854	4.82	0.811
Buffalo	5,748.28	255.395	1.820	.5299993	5.46	0.439
Cleveland	3,237.42	557.390	1.682	.485377	5.42	0.634
Dallas	15,791.8	2,640.70	1.642	.5007595	5.68	0.904
Denver	10,291.6	820.065	1.677	.4847352	5.26	1.103
Los Angeles	33,598.5	5,353.15	1.946	.5439533	5.66	0.826
Memphis	943.780	161.918	1.598	.5122321	5.42	0.622
New Orleans	4,680.44	2,494.89	1.607	.5044123	4.98	0.455
New York	10,698.6	3,920.50	1.942	.4969846	5.66	0.907
Philadelphia	18,553.9	1,314.94	1.753	.5386561	4.94	0.513
Pittsburgh	7,222.10	371.759	1.696	.518966	5.34	0.590
Portland	27,837.6	3,748.69	1.816	.4742139	6.82	1.339
Sacramento	10,797.9	2,643.62	2.027	.5164207	5.20	0.566
St. Louis	15,573.1	1,759.15	1.659	.4612551	5.38	0.559
Salt Lake City	10,518.1	3,178.09	1.706	.4790144	4.82	1.232
San Diego	28,028.4	3,861.91	1.995	.5033848	4.66	0.555
San Jose	7,389.30	1,756.10	1.978	.482815	6.60	1.785
Seattle	308.920	173.413	1.818	.533732	5.80	0.992

Table 2 (continued):

City	Income		Population	
	Mean	Std. Dev	Mean	Std. Dev.
Atlanta	33,726.6	1,363.49	4,722,731	266,049
Baltimore	37,946.4	3,245.09	2,619,601	33,884.5
Boston	44,604.4	3,495.06	1.25e+07	1.79e+07
Buffalo	30,099.8	2,393.78	1,152,185	11,612.8
Cleveland	33,614.6	2,285.86	2,131,293	15,552.1
Dallas	35,630.4	2,513.18	5,614,458	239,809
Denver	40,343.0	2,525.75	2,310,243	68,721.8
Los Angeles	34,636.8	3,152.73	1.27e+07	133,624
Memphis	31,968.0	2,240.82	1,237,881	21,719.1
New Orleans	31,459.2	5,007.75	1,246,528	143,138
New York	43,011.8	3,981.28	1.86e+07	119,090
Philadelphia	38,113.6	3,298.86	5,756,681	39,429.7
Pittsburgh	34,047.6	2787.588	2,396,795	21,549.7
Portland	33,543.6	1,929.70	2,044,769	58,546.9
Sacramento	32,933.8	2,597.14	1,967,910	75,499.2
St. Louis	33,966.2	2,338.69	2,750,660	28,415.4
Salt Lake City	30,706.2	2,619.25	1,020,235	34,200.4
San Diego	37,068.4	3,654.64	2,919,620	31,469.7
San Jose	48,716.2	3,780.91	1,746,232	17,359.3
Seattle	40,408.2	3,243.30	3,159,026	63,424.1

Figure 11: Average Gas Prices across All Cities, 2001-2006

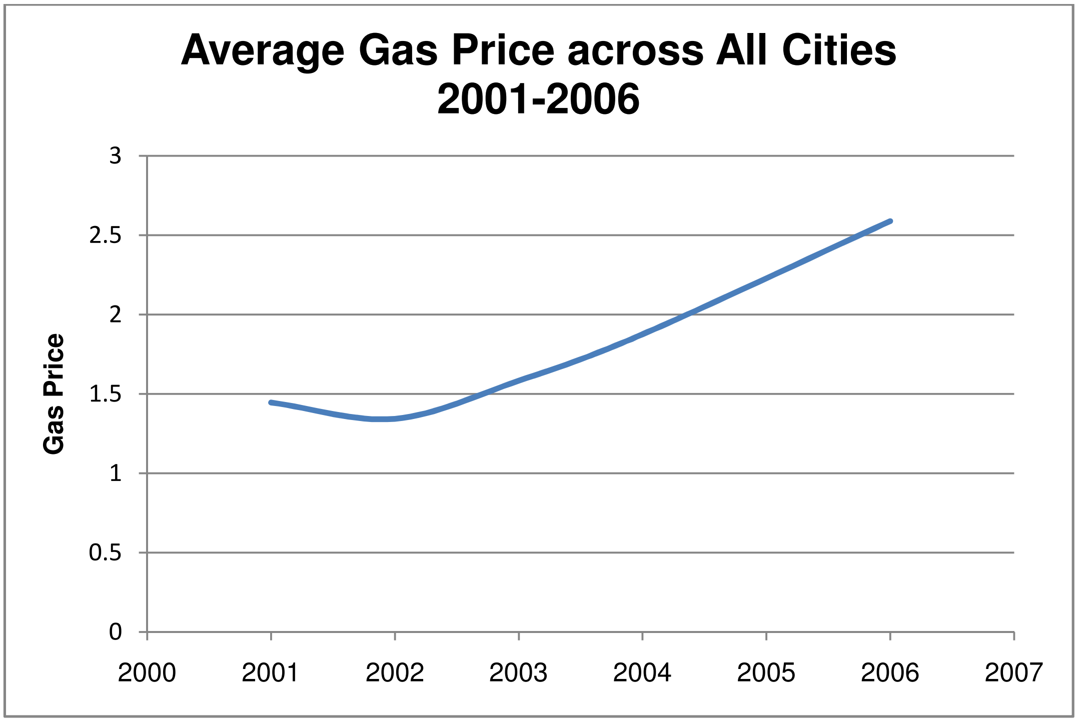


Figure 12: Map of MARTA's Bus and Rail Networks

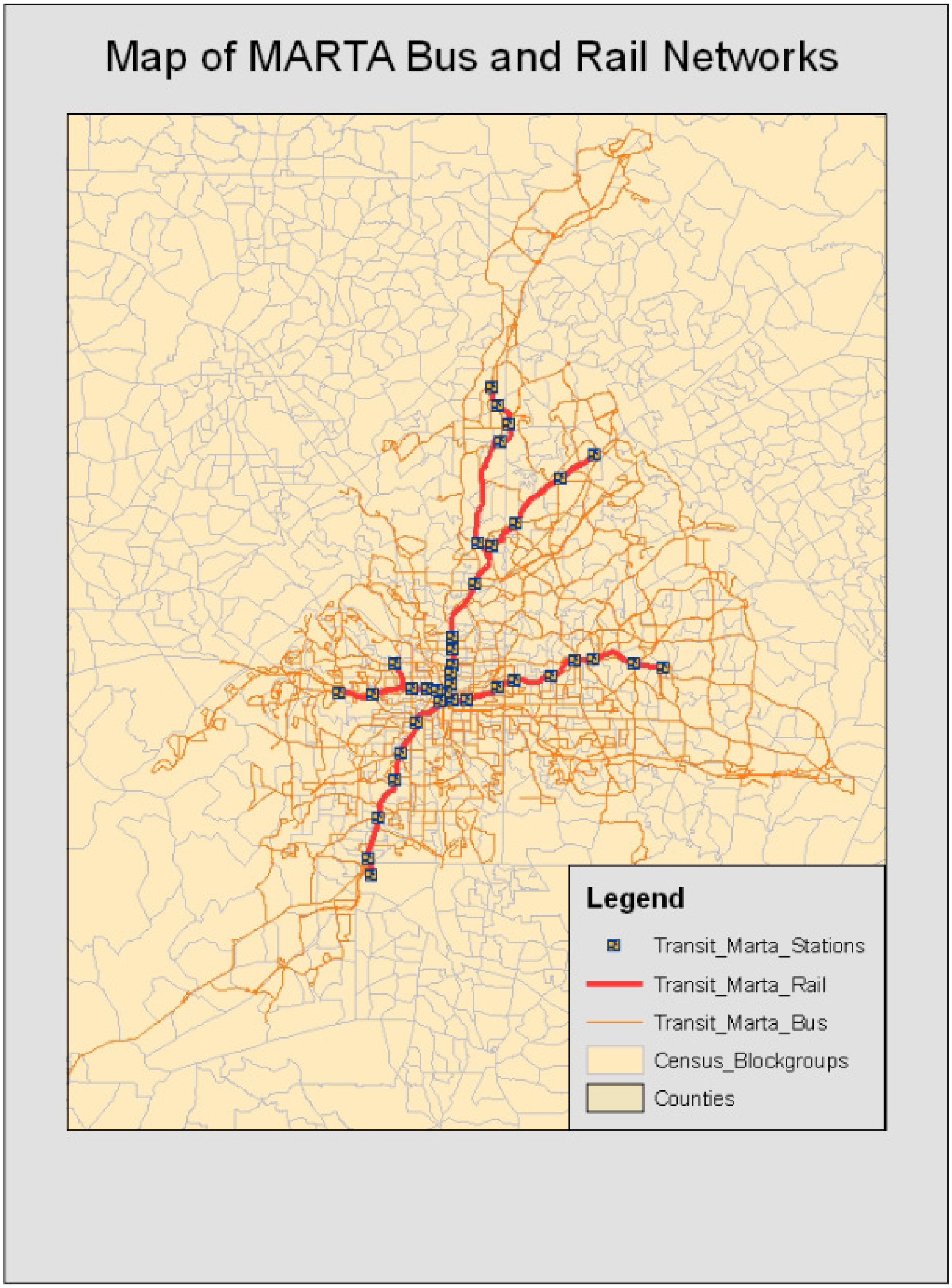


Figure 13: MARTA Rail Map

From MARTA's website

Table 3: OLS Regressions of Gas Prices (Log (gas prices)) on Total Entries (Log (total entries))

Variable	Total entries	Log (total entries)	Log (total entries)	Total entries
	(1)	(2)	(3)	(4)
Gas	18,824.3 (12.75) ***		0.11090 (10.03) ***	
Log (gas)		0.28210 (7.81) ***		48,089.0 (10.18) ***
January	-7,350.02 (-1.81) *	-0.08311 (-2.76) ***	-0.06215 (-2.01)**	-10,577.1 (-2.69) ***
February	1,794.08 (0.8)	-0.01225 (-0.81)	0.00901 (0.55)	-1,484.25 (-0.72)
March	3,334.51 (1.46)	0.00055 (0.04)	0.02239 (1.38)	-64.1466 (-0.03)
April	2,961.67 (1.64) *	(dropped)	0.01916 (1.6)	(dropped)
May	-7,557.63 (-2.73) ***	-0.05690 (-2.8) ***	-0.04511 (-2.28) **	-9,289.15 (-3.32)***
June	(dropped)	-0.00765 (-0.65)	(dropped)	-1,034.72 (-0.58)
July	-7,255.43 (-3.51) ***	-0.06118 (-4.28) ***	-0.04861 (-3.79) ***	-9,114.22 (-4.12)***
August	563.243 (0.21)	-0.01877 (-1.12)	-0.00084 (-0.05)	-2,191.86 (-0.81)
September	3,956.93 (1.36)	0.00576 (0.28)	0.021283 (1.03)	1,619.98 (0.56)
October	10,813.4 (4.65) ***	0.04435 (3.14) ***	0.064203 (4.21) ***	7,767.82 (3.60)***
November	2,484.25 (0.65)	-0.01625 (-0.58)	0.00301 (0.11)	-438.958 (-0.12)
December	-3,747.27 (-0.85)	-0.06263 (-1.69) *	-0.04856 (-1.31)	-5,774.80 (-1.31)
Sunday	-107,701 (-40.39) ***	-0.82221 (-36.05) ***	-0.82220 (-36.21) ***	-107,702 (-40.15)***
Monday	-7,597.03 (-2.1) **	-0.04685 (-1.67)*	-0.04686 (-1.68)*	-7,595.42** (-2.09)
Tuesday	-2,221.41 (-0.73)	-0.00732 (-0.30)	-0.00743 (-0.31)	-2,203.26 (-0.71)
Wednesday	1,382.07 (0.50)	0.020511 (1.03)	0.02030 (1.02)	1,418.44 (0.50)
Thursday	(dropped)	(dropped)	(dropped)	(dropped)
Friday	3,495.47	0.02862	0.02866	3,488.72

Variable	Total entries	Log (total entries)	Log (total entries)	Total entries
	(1.20)	(1.38)	(1.38)	(1.19)
Saturday	-72,554.4 (-24.94) ***	-0.47066 (-20.9)***	-0.47054 (-20.92)***	-72,575 (-24.83)***
Constant	137,601 (23.42)***	11.8759 (247.43)***	11.8312 (257.51) ***	144,674 (23.97)***
R^2	0.7844	0.7694	0.7731	0.7789
F-statistic	335.47	221.16	228.55	319.57

NOTE: Two of the four regressions in Table 7 include transformed variables (the log of gas prices and the log of total entries) in order to facilitate interpretation of the regressions. Also, figures in parentheses represent t-statistics.

Table 4: Regression of Gas Prices, Month Dummies on Total Number of Entries by Day of the Week

Variable	Su	M	T	W	Th	F	S
Gas prices	7,304.0 (3.10)***	23,472 (4.62)***	20,985 (4.74)***	20,418 (6.15)***	25,186 (5.42)***	21,965 (6.29)***	12,238 (3.85)***
Adjusted R^2	0.2332	0.2444	0.3366	0.3741	0.3563	0.3943	0.1612

Table 5: Regression of Gas Prices, Day Dummies on Total Number of Entries by Month

Month	Gas prices	Adjusted R^2
January	20,562 (2.85)***	0.6844
February	15,569 (5.18)***	0.9495
March	3,336.4 (0.86)	0.9380
April	15,346 (4.47)***	0.9707
May	15,245 (2.44)**	0.8529
June	16,024 (9.70)***	0.9845
July	29,008 (11.29)***	0.9088
August	26,091 (5.80)***	0.8021
September	27,184 (8.91)***	0.7993
October	25,637 (8.63)***	0.9050
November	13,604 (1.95)*	0.6176
December	-168.14 (-0.02)	0.4804

Table 6: Regression of Precipitation, Temperature on Total Entries into MARTA Stations

Variable	(5)	(6)	(7)
Precipitation (mm)	-291.86 (-3.03)***	-	-
Min temperature (ºF)	-226.19 (-1.31)	-	-
Max temperature (ºF)	396.29 (2.25)**	-	-
Light	-	-3,016.7 (-1.29)	-
Moderate	-	-8,017.9 (-1.93)*	-
Heavy	-	-10,984.3 (-3.16)***	-
Cold	-	-216.88 (-0.08)	-
Hot	-	-587.20 (-0.22)	-
Crummy	-	-	6,160.6 (1.06)
Crummier	-	-	6,931.4 (1.1)
Crummiest	-	-	-36,359.6 (-12.94)***
Sucky	-	-	-3,494.5 (-0.78)
Suckier	-	-	-4,918.2 (-0.66)
Suckiest	-	-	-8,701.0 (-1.27)
January	-107,848 (-37.39)***	-111,275 (-45.76)***	-108,042 (-37.78)***
February	-8,839.5 (-2.23)	-12,222 (-3.37)***	-7,791.5 (-1.98)**
March	-3,323.0 (-0.98)	-6,349.3 (-2.08)*	-2,536.2 (-0.75)
April	854.57 (0.27)	-2,504.9 (-0.92)	1,109.3 (0.35)
May	(dropped)	-3,524.9 (-1.08)	(dropped)
June	3,298.8 (1.02)	(dropped)	3,298.0 (1.01)
July	-73,271	-76,749	-72,842

Variable	(5)	(6)	(7)
	(-23.32)***	(-27.78)**	(-23.01)***
August	-17,832 (-3.1)**	-24,610 (-5.02)***	-20,995 (-4.75)***
September	-9,970.2 (-2.38)**	-15,904 (-4.69)***	-10,064 (-4.73)***
October	-5,332.5 (-1.6)	-9,693.4 (-3.19)***	-3,988.0 (-1.91)*
November	-1,625.0 (-0.55)	-5,478.5 (-1.88)*	(dropped)
December	-7,622.4 (-2.35)**	-10,154 (-2.76)***	-4,215.7 (-1.42)
Sunday	(dropped)	(dropped)	5,981.6 (2.66)***
Monday	-9,255.0 (-3.27)***	-10,299 (-3.59)***	-4,828.1 (-1.81)
Tuesday	-5,601.3 (-1.77)*	-6,098.7 (-1.93)*	-700.05 (-0.22)
Wednesday	-3,269.3 (-0.91)	-6,069.8 (-1.6)	-124.29 (-0.04)
Thursday	-1,432.7 (-0.44)	-5,711.4 (-1.69)*	-45.934 (-0.02)
Friday	-14,112 (-2.92)***	-19,598 (-4.4)***	-13,826 (-3.67)***
Saturday	-20,979 (-4.36)***	-27,123 (-5.72)***	-22,414 (-5.44)***
Constant	183,831 (19.17)***	208,695 (63.6)***	197,928 (72.8)***

Test of joint significance		2.90	29.02

Table 7: OLS Regressions Showing Effects of Gas Prices, Unemployment Rates, Income, Population, and Year Dummies on Unlinked Trips

Variable	(7)	(9)	Variable	(8)
Gas	-16,893 (-1.26)	-11,948 (-1.26)	Log(gas)	1.8172 (1.68)
Unemployment	-6,647.8 (-2.18)**	-813.45 (-1.02)	Log(unemployment)	-2.3695 (-2.43)**
Income	0.5032 (1.02)	0.5032 (1.26)	Log(income)	-1.1738 (-1.26)
Population	0.0010 (4.05)***	-4.1E-05 (-0.46)	Log(population)	0.7388 (5.98)
2001	-4,938.9 (-0.74)	(dropped)	2001	0.6047 (0.83)
2002	(dropped)	62.06 (0.03)	2002	1.2522 (1.58)
2003	6,537.4 (0.99)	2,146.6 (1.07)	2003	1.1044 (1.65)*
2004	7,623.2 (0.91)	4,908.4 (1.17)	2004	0.7169 (1.31)
2006	13,890 (0.84)	13,429 (1.25)	2006	(dropped)
Constant	56,069 (2.05)**	21,362 (1.14)	Constant	12.737 (1.39)

Figure 14: Ridership and Median Household Income in Atlanta

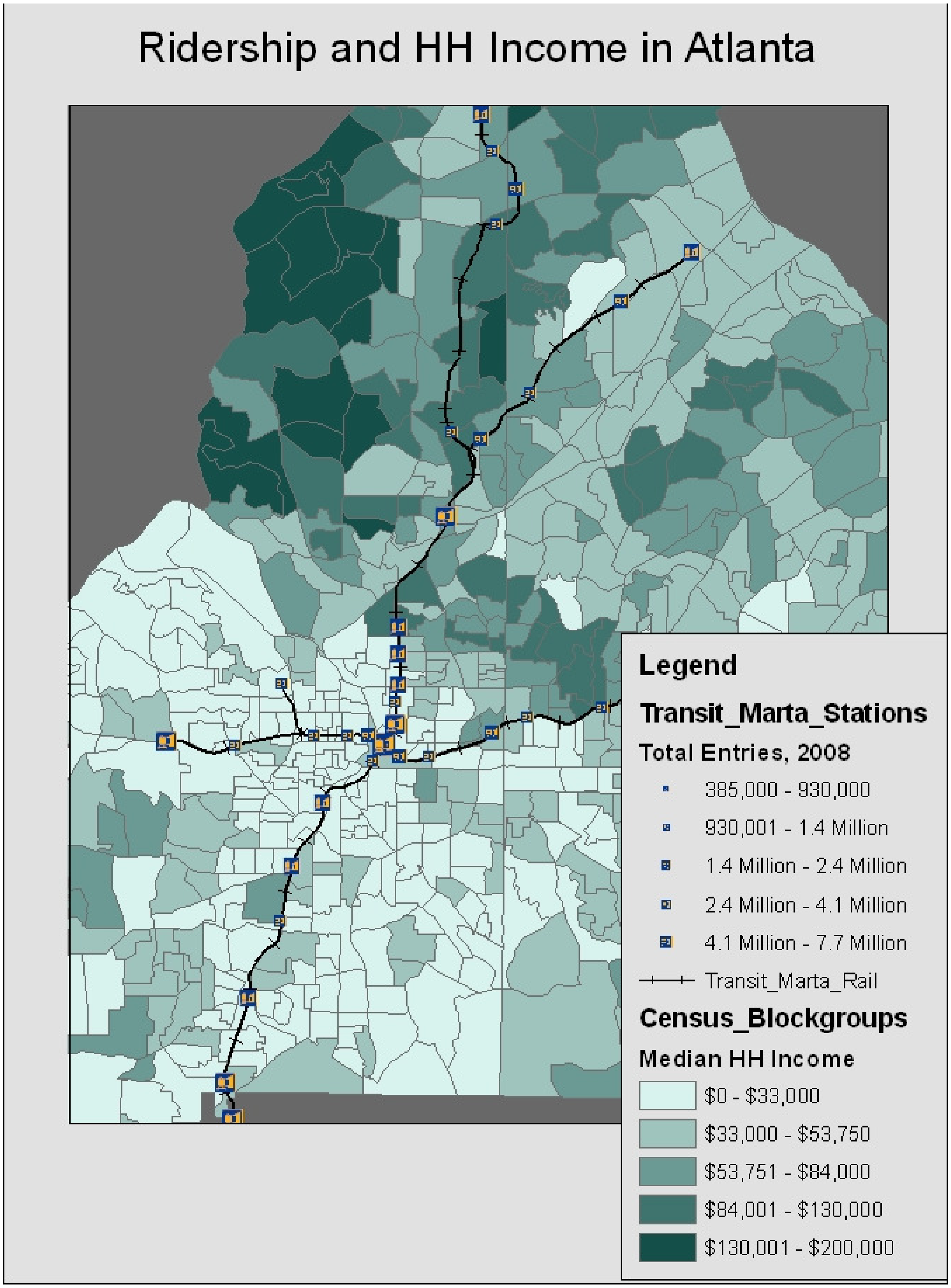


Figure 15: Ridership Patterns of African-American Population in South Atlanta