EFFECTS OF E85 FUELING STATIONS AND STATE INCENTIVES ON PRIVATE FLEX FUEL VEHICLE DEMAND

A Thesis
Presented to the Faculty of the Graduate School
of Cornell University
in Partial Fulfillment of the Requirements for the Degree of
Master of Science

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August 2014

ABSTRACT

The main goal of this paper was to examine the single directional impact of fueling stations that offer E85 on vehicles that carry the fuel – flex fuel vehicles (FFVs). Another objective was to evaluate the effectiveness of state incentives aiming at promoting private FFV adoption. The study explored a panel data of FFVs sold to private consumers in the 366 Metropolitan Statistical Areas (MSA) in the U.S. from 2007 to 2012, the number of E85 fueling stations in the corresponding areas and period, and state incentives including tax credit, purchase rebates, purchase loans, and tax exemption. Using fixed-effects linear model, random-effects tobit model, and fixed-effects instrumental variable model with fueling station incentives and government FFV fleet incentives as instruments, the results confirmed that increasing the density of E85 fueling stations leads to increased FFV demand. Specifically, increasing 1 station per million people increases FFVs' share in total number of vehicles sold by 0.1%. Moreover state income tax credit and purchase rebates are effective at stimulating FFV demand, while the results are inconclusive for purchase loans and tax exemption, due to limited variability and number of MSAs that offer these kinds of incentives.

BIOGRAPHICAL SKETCH

Pei Zhu was born on November 26, 1988. She grew up in Beijing China, graduated from Singapore American High School in 2007, and received her Bachelor of Arts in Mathematics and Economics from Cornell University in 2011. With strong interest in the energy industry, she continued to pursue a Master of Science degree in Applied Economics and Management in Cornell University. After passing her Master's exam in 2013 she went on to work for an oil and gas major in London where she applied her skills in market analysis and quantitative research. This research project gave her the opportunity to learn about the ethanol industry and to examine one of the hottest topics in the energy industry in the U.S.

ACKNOWLEDGEMENTS

I would like to sincerely thank my committee chair Professor Shanjun Li for his help throughout this project.

I would also like to thank my committee member Professor Todd M. Schmit for his dedication and help with the final product of this project.

Last but not least, I would like to thank my parents for their constant love and support.

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1 Introduction

As part of the effort to increase the consumption of renewable fuels and decrease energy dependence, the U.S. government has been promoting the use of alternative fuels in transportation. Transportation energy use comprises a large part in total energy use, and changing the energy structure of transportation will have a significant impact on the national energy consumption structure. Ethanol is among the many forms of alternative fuels to choose from in transportation. It is domestically produced and can be produced in large quantities; it requires fewer technological breakthroughs and less infrastructure development than is needed to support electric vehicles and fuel cell vehicles; it also emits lower air pollutants than gasoline. Therefore its widespread adoption can alleviate energy dependency and environmental problems. However one of the current obstacles or disadvantages of ethanol powered vehicles (flex-fuel vehicles) is the limited availability of the fuel E85.

The relationship between E85 fueling stations and flex-fuel vehicle (FFV) demand is similar to the network effect in the digital industry, specifically the relationship between hardware and software providers (Corts, 2010). The successful diffusion of the product (flex fuel vehicles) is often contingent upon the availability of complementary products (E85 fueling stations). Increasing the availability of the fuel will let consumers be more aware of the fuel and flex fuel vehicles, make it more convenient for FFV drivers, decrease the cost and increase the expected utility of owning an FFV, therefore making flex fuel vehicle a more attractive buying option for consumers. In this paper I use panel data on consumer vehicle purchases in 366 Metro Statistical Areas (MSAs) from 2007 to 2012 and the number of E85 fueling stations additions during the period to examine whether the data supports the idea that increasing the number of fueling stations that provide E85 increases flex fuel vehicle demand.

Just as there is interdependence between the hardware-adoption decisions of consumers and the supply decisions of software manufacturers (Gandal, Kende, and Rob, 2000), there's also interdependence between the vehicle buying decision of consumers and the supply decision of retail fuel providers. This inter-dependence in demand generates a feedback mechanism (Nair, Chintagunta, and Dube, 2003). Higher demand for FFVs stimulates fueling stations' profits, leading to a greater number of stations. Increased fueling station availability, in turn, enhances the value of owning an FFV leading to subsequent adoption. The strength of such feedback effects varies from system to system, so just how important they are is an empirical question. The aim of this paper is to undertake such an empirical study where I examine the single directional impact of fueling station supply on flex fuel vehicle demand. Therefore an important feature of the estimation procedure is the control for the potential endogeneity of FFV demand on E85 station supply. In particular, E85 station provision depends on total demand for flex fuel vehicles and, at the same time, total current demand for FFVs depends on E85 station availability. Since they are determined simultaneously rather than sequentially in the market, I use instrumental variables to deal with this problem.

Another disadvantage of using ethanol in cars lies in its lower energy content than gasoline; although E85 price has generally been lower than gasoline price, thus to some extent offsetting this disadvantage. To further offset these disadvantages and increase alternative fuel use in transportation, state governments have implemented various incentives to attract more consumers by decreasing the cost to purchase an FFV and to use E85 as the fuel. Previous research has found that federal income tax incentives contribute significantly to the growing market share of hybrid vehicles (Beresteanu and Li, 2011). To examine whether state incentives facilitate the diffusion of flex fuel vehicles and which type of incentives is the most effective and therefore deserves more resources to be allocated to it, I collected state incentives data for private FFV consumers and estimate different incentives' effects.

The results suggest that investing in resources in increasing the provision of E85 by fueling stations and providing income tax credit and purchase rebates for consumers are effective in promoting flex fuel vehicle adoption by private consumers.

2 Industry Background

2.1 Ethanol

Ethanol as an alternative fuel

U.S. energy consumption is expected to grow over 18 percent by 2030. Biofuels must continue to play a significant role as the country works aggressively towards diversifying energy sources and providing a balanced portfolio of energy solutions to help meet this growing demand for energy.

Ethanol is a renewable fuel made from various plant materials collectively known as "biomass." More than 95% of U.S. gasoline contains ethanol in a low-level blend to oxygenate the fuel and reduce air pollution.

Ethanol is primarily produced from the starch in corn grain in the United States. Some studies suggest that corn-based ethanol has a negative energy balance, meaning that it takes more energy to produce the fuel than the amount of energy the fuel provides. However, recent studies have shown that corn ethanol yields 25% more energy than the energy invested in its production (Hill et al., 2006).

A more promising long-term solution is cellulosic ethanol, which is produced from non-food based feedstocks such as corn stover (leaves, stalks, and other leftover parts), rye straw, wood pulp, and switchgrass. Biomass used to power the process of converting non-food-based feedstocks into cellulosic ethanol is expected to reduce the amount of fossil fuel energy used in production. Since non-food-based feedstocks require less fossil fuel energy than corn to produce ethanol, its use could improve the energy balance of ethanol.

Another potential benefit of cellulosic ethanol is that it produces lower levels of greenhouse gas emissions. The carbon dioxide released when ethanol is burned is balanced by the carbon dioxide captured when the crops are grown to make ethanol. This differs from petroleum, which is made from plants that grew millions of years ago. On a life cycle analysis basis, corn-based ethanol production and use reduces greenhouse gas emissions (GHGs) by up to 52% compared to gasoline production and use. Cellulosic ethanol use could reduce GHGs by as much as 86%.

A 2005 study conducted by the U.S. Department of Agriculture and Oak Ridge National Laboratory estimated that by 2030, ethanol from corn and cellulose could replace 30% of U.S. oil consumption – about the same as the United States currently imports from OPEC nations. Called the Billion Ton Study, it assumes that one billion tons of organic material could be used, with no loss of corn for food or feed, from resources such as forest waste organic residue, and energy crops such as switchgrass.

In terms of job opportunities, ethanol production creates jobs in rural areas where employment opportunities are needed. According to Renewable Fuels Association, ethanol production in 2011 supported more than 400,000 jobs across the country, $42.4 billion to the gross domestic product, and $29.9 billion in household income.

Ethanol as an alternative transportation fuel

According to EIA's Annual Energy Review published in September 2012, U.S. petroleum imports account for 44.7% of total demand in 2011, and 70% of the total petroleum demand comes from the transportation sector. Heavy dependence on foreign petroleum makes U.S. economy more susceptible to risks such as trade deficits, supply disruption, and price changes.

The idea of running cars on ethanol is not new. Henry Ford designed the first Model T to run on ethanol so that farmers could produce their own fuel. In the 1970s, when two U.S. presidents trumpeted the use of ethanol to help toward greater independence from petroleum, the recipe was called "gasohol"—a mixture of 90 % gasoline and 10 % ethanol. While some import and older domestic cars had difficulty operating on the blend, all vehicles sold in U.S. from approximately 1980 forward can run on gasohol. The Renewable Fuels Association's 2012 Ethanol Industry Outlook calculated that in 2011 the ethanol industry replaced the gasoline produced from more than 485 million barrels or 15.7% of imported oil. Ethanol represents 25% of domestically produced and refined motor fuel for gasoline engines.

The use of ethanol is required by the federal Renewable Fuel Standard (RFS), a federal program that requires transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels.

The RFS originated with the Energy Policy Act of 2005 and was expanded and extended by the Energy Independence and Security Act of 2007 (EISA). The RFS program requires renewable fuel to be blended into transportation fuel in increasing amounts each year, escalating to 36 billion gallons by 2022. Each renewable fuel category in the RFS program must emit lower levels of greenhouse gases relative to the petroleum fuel it replaces.

E85 as an alternative transportation fuel

E85 is a high-level ethanol blend containing 51% to 83% ethanol, depending on geography and season. It is considered an alternative fuel under the Energy Policy Act of 1992 (EPAct). It can be used in flexible fuel vehicles (FFVs), a vehicle type that runs on either E85 or gasoline, and are commonly available from domestic and foreign automakers.

The E85 blend is used in gasoline engines modified to accept such higher concentrations of ethanol, and the fuel injection is regulated through a dedicated sensor, which automatically detects the amount of ethanol in the fuel, allowing it to adjust both fuel injection and spark timing accordingly to the actual blend available in the vehicle's tank.

Ethanol contains about 33% less energy per gallon than gasoline, and E85 has about 27% less energy per gallon than gasoline. Therefore E85 FFVs have a lower mileage per gallon than gasoline. The amount of reduction in mileage is highly dependent upon the particulars of the vehicle design, the exact composition of the ethanol-gasoline blend, and state of engine tune. Based on EPA tests for all 2006 E85 models, the average fuel economy for E85 vehicles was 25.56% lower than unleaded gasoline. However other than lower gas mileage, there's little difference when using E85 or gasoline, and E85 FFVs offer increased vehicle power and performance.

2.2 Flex Fuel Vehicles

Flexible fuel vehicles (FFVs) have an internal combustion engine and are capable of operating on gasoline, E85, or a mixture of the two. FFVs are different from conventional gasoline vehicles because they have to accommodate the unique fuel properties of ethanol. Since ethanol is corrosive, FFVs use special fuel tanks, lines, and pumps designed to be more corrosion resistant. Their emissions systems are also specially designed to recognize and compensate for higher blends of ethanol. Other than employing an ethanol-compatible fuel system, FFVs are similar to their conventional gasoline counterparts. The only downside is that the fuel economy is lower when FFVs run on ethanol. Their power, acceleration, payload, and cruise speed are comparable whether running on ethanol or gasoline. Flexible fuel vehicles qualify as alternative fuel vehicles (AFVs) under the Energy Policy Act of 1992.

Conventional gasoline vehicles could technically be converted to FFVs; however, this requires extensive modifications throughout the fuel system and electronic engine-control system, which is prohibitively expensive to do once the car leaves the factory.

The American E85 flex-fuel vehicle was developed to run on any mixture of unleaded gasoline and ethanol, anywhere from 0% to 85% ethanol by volume. Both fuels are mixed in the same tank, and E85 is sold already blended. In order to reduce ethanol evaporative emissions and to avoid problems starting the engine during cold weather, the maximum blend of ethanol was set to 85%. There is also a seasonal reduction of the ethanol content to E70 (called winter E85 blend) in very cold regions, where temperatures fall below 0 ℃ (32 ℉) during the winter. In Wyoming for example, E70 is sold as E85 from October to May.

2.3. Environmental Impact

There have been many studies done to compare and contrast the different emissions of E85 and gasoline and the effects these emissions have on the environment. On the positive side, E85 is less volatile than gasoline or low-volume ethanol blends, it results in fewer evaporative emissions. Using E85 also reduces carbon-monoxide emissions and provides significant reductions in emissions of many harmful toxics, including benzene, a known human carcinogen. E85 increases emissions of acetaldehyde, which EPA lists as a probable carcinogen. However, acetaldehyde is not nearly as bad as some of the emissions from gasoline, as noted by James Cannon to Consumer Reports, president of Energy Futures, an alternative-transportation publication.

Otherwise, studies and tests have shown very little consistency if any at all because there are too many variables involved: the make and model of the vehicle, the way in which the ethanol was produced and the vehicles' overall fuel efficiency, which all play a large role in the overall outcome of each study. To address the problem of inaccuracy, National Renewable Energy Laboratory combined data from all applicable emissions studies and showed that on average all emissions that are federally regulated showed a decrease or no statistically significant difference between E85 and gasoline (Johnson and Melendez, 2007). Later in 2011, the US Environmental Protection Agency published a report later on air quality impacts of increased use of ethanol under the US' Energy Independence and Security Act. Similarly, it finds that the EISA renewable fuel standards have relatively little impact on national average ambient concentrations of most air toxics, while indicating that significant uncertainties were associated with all results due to limitations in available data (Cook at al., 2011). A most recent paper in 2014 still finds no definitive answer to the question of whether air pollutant emissions (NO_x and volatile organic compounds) would be impacted as a result of the increased use of ethanol in the on-road FFV fleet (Hubbard at al., 2014).

2.4 E85 Fueling Stations

Low-level ethanol blends are already in more than 95% of the gasoline sold in the United States. Low-level blends require no special fueling equipment and can be used in any gasoline vehicle. E85 fueling equipment is only slightly different than petroleum fueling equipment, but the costs are higher.

Selling E85 can be a sound business decision for many gasoline retailers, because it can help alleviate some of the pressure they experience in the competitive gasoline market. This pressure comes from the decreasing margins of more than $0.005/gallon per year in years 1994 to 2006 from the already thin margin. The main causes of the low margins are the hardly differentiated nature of the product, the transparency of prices, the increased location competition, and the existence of hypermarts.

The solutions to station owners include offering higher margin goods, such as in-store goods, prepared food, and car wash. In addition, offering E85 can increase customers' exposure to these higher margin goods. It does so in three ways:

a. E85 can secure reliable fleet customers because many federal, state, and local governments, as well as private fleets, are required to use E85. This customer base for E85 will also increase the customer base for higher margin goods in the stations.

b. E85 can draw new non-fleet customers to the store if these customers drive flex-fuel vehicles and desire to fuel at the station that offers E85. As the number of FFVs on the roads increase each year, we would expect that more customers will choose to fuel at E85 stations.

c. E85 customers fuel more often because of higher concentration ethanol's lower energy content per gallon than regular gasoline.

Offering E85 can also help differentiate a fueling station by its green, cutting-edge, and patriotic image. As successful differentiation can sometimes overcome the slightly disadvantages of price and location, station owners choose differentiation to increase their profit margin. Other ways to differentiate a station include improving the appearance of the station. A remodeling project that the average station does every 11.5 years costs about $228,000. In contrast, the costs of E85 equipments that last at least 15 years range from $2,500 for simple conversion of a gasoline tank to $200,000 for all new equipment in an expensive location. Therefore it's less expensive to offer E85 as a way to differentiate than remodeling the station (Johnson, 2007).

Even if we ignore E85 stations' competitive advantages to gasoline stations, E85 projects can still be profitable investments. However the profitability depends on many factors. The National Renewable Energy Laboratory (NREL) developed a model to test the influence of different factors on E85 station investment profitability. The model revealed that the most important variable in determining profitability is the throughput of E85. Therefore guidance is offered to help the station owner assess the potential E85 throughput. Guidance is also offered to help retailers assess the gross margin they might expect to earn in offering E85.

3 Literature Review

A very closely related paper by Kenneth Corts uses data from six states to examine the effects of government fleet adoption of FFVs on retail E85 stations. There are many differences between his approach and mine. While he didn't have sufficient data for all 50 states, I examine differences across all 366 MSAs. While he focused specifically on government fleet adoption, I look at different kinds of incentives adopted on the state level, mainly focusing on the incentives targeted towards FFV consumers and fueling station owners. Moreover, while he examines the effects on the number of E85 stations in each state, I examine the effects on FFV demand. In other words, while he uses demand on FFV (specifically government demand) as explanatory variable, I regard the demand (both government and private) as explained variable. Instead of treating the number of stations in different areas as dependent variable, I treat it as an implicit explanatory variable on FFV demand, as predicted by the level of state incentives on building E85 fueling stations. I predict that the more incentives a state has on building E85 fueling stations, the more fueling stations the state will have and therefore the demand for FFVs should increase.

He used data on FFV registration (both government and private registrations), list of E85 stations and refineries in each state, number of gas stations and car dealers, as well as different measurements of demographics in each state.

For the model, he assumed free entry into the market, then an individual gas station owner's decision whether to offer E85 depends on the fixed cost of entry, the cost of fuel, the demand for E85, and the decisions of other potential entrants. In equilibrium the number of stations is determined by the first three factors. Then he control for these factors and mainly looks at the effect of number of government FFVs. Here the control variables also include differences in state-level subsidies and regulations, which affect fixed costs of entry and variable cost of fuel in various ways. In my analysis, on the other hand, these are the things that I examine with emphasis.

The main identification is differences in the number of government FFVs that is not explained by state fixed effects or by differences in population and population density. To account for the possibility of endogeneity where the number of government FFVs is determined and responds to E85 availability, he uses all government vehicles as instrument for government FFVs. To deal with the possibility that private FFVs may also be correlated with unobserved determinants of the number of E85 stations, he uses the number of FFV dealer-brands to instrument for private FFV registrations.

Because the value of the dependent variable cannot take negative values as the number of E85 stations can't be negative, this is a regression with a censored dependent variable. Tobit regression is therefore used by implementing Stata's Newey's two-step estimation.

To address for spatial correlation of errors, Moran's statistic is used, and the tests fail to reject the null hypothesis that errors are spatially uncorrelated.

The results of various specifications of the model support the conclusion that there is a significant and sizable effect of government FFVs on the presence of E85 stations.

Corts points out that the determinants of demand for alternative fuel vehicles remains an important topic for further research, which is what I examine here. He also points out that further research can attempt to assess the effects of government incentives other than mandates on government fleet FFV acquisition, which is what I do in this paper regarding different tax credit and subsidies.

4 Data Description

4.1 Data Overview

The goal is to investigate the effects of state incentives and the addition of fueling stations on FFV demand. These effects can only be seen over time by comparing periods of time with and without the incentives and/or fueling stations in place. Therefore I use panel data to examine this dynamic phenomenon.

There are many factors that contribute to the differences in FFV share of all new vehicles sold across MSAs over time. In order to focus on the effects of state incentives and the number of fueling stations, I have to control for additional effects. Panel data allows me to control for unobservable variables. In this case, my panel data consists of quarterly data of flex-fuel vehicles sold from 2007 to 2012 across 366 MSAs in the U.S. This cross-sectional time-series data controls for variables that change over time but do not change across regions (i.e. national policies, federal regulations, international agreements, etc.). In other words, it accounts for individual heterogeneity.

There are 24 observations per MSA measured from t=1 to t=24 and a total of 8784 observations in the dataset. Quarterly data on new vehicles sold including the number of FFVs sold are obtained from R. L. Polk & Co, a marketing company. The data includes cars and light-duty trucks sold to private consumers.

- Dependent Variable

Since we want to find out what drives new FFV demand rather than all vehicles demand in general, I use new FFV's share by calculating the percentage of FFVs sold in total new vehicles sold on the left hand side of the models.

- E85 Fueling Stations

Data on E85 fueling stations is from U.S. Department of Energy's Alternative Fuels Data Center. To account for differences in MSA size, I calculate the number of E85 fueling station per million people each quarter and use this variable in the model to indicate the relative density of E85 fueling stations.

There might be a time lag between when the stations are built and when people get to know where they are. In addition, people might not need to or make the decision to buy a new car right away. Therefore the effects of new fueling stations on FFV demand may not be seen right away after the stations are built. If the information diffuses quickly, people change cars frequently or the number of new drivers is high, the effects of number of stations now may be seen just one quarter after. On the other hand, it may take longer for more people to know about the stations, people change cars less frequently, or the rate of new drivers is lower, in which case I assume the period of time after which the effect can be seen could be as long as one year. Therefore I record the number of stations in the previous quarter and in the previous year separately to account for the lagged station effects and to examine whether previous quarter's or previous year's number of stations predicts current demand more accurately.

- State incentives for FFV consumers

State incentives specifications for FFV consumers are taken from U.S. Department of Energy's Alternative Fuels Data Center. Each incentive type for potential private FFV consumers is considered a separate independent variable. Four incentive variables are generated: income tax credit, tax exemption, fuel purchase rebate, and purchase loans. The last two are omitted in the models because of their very limited applicability. As the states have varying measures of provisions, it's impractical to assign comparable values to each state. Therefore the incentives are treated as dummy variables that take on values of either 0 or 1. For states providing the specified incentive during part of the period in study, the period of time during which the incentive is in effect takes on value of one, otherwise zero is assigned. All other states are assigned zero for the specified incentive variable over the period in study.

- Instrumental variables

State incentives for E85 fueling stations were also from U.S. Department of Energy's Alternative Fuels Data Center (AFDC). There are three types of station incentives: fueling infrastructure grant, fueling tax credit, and fueling infrastructure loan. Since all states' provisions of these incentives are in terms of maximum amount of money allowed, the exact value is assigned to each incentive type variable for the period of time from when the incentive was implemented to the time of its termination. The incentive variable takes value zero for the rest of the time between 2007 and 2012.

As forcing government FFV fleet adoption increases the incentive for private gasoline stations to offer E85 by creating demand for the fuel (Corts, 2010), state incentives for government FFV adoption are used as another instrument for private FFV adoption. Incentives targeted at government vehicles include tax exemption, fuel purchase rebate, and purchase loans. Because government fleet incentives has to translate into government fleet adoption first, before translating the effect into fueling station adoption, I use these instruments (government fleet purchase rebates and government fleet tax exemption) lagged for one more quarter than direct E85 fueling station incentives.

For all the state incentives, most of the starting dates and ending dates of incentives are taken from AFDC and the referenced state laws and state codes. However some dates are based on historical news articles where the implementation of the incentive is clearly stated when they are not available or not clearly specified in state law. When there's no specification as to the expiration date, the incentive is assumed to be currently applicable. It's noted that in a few cases the laws have many amendments and revisions that it's unclear as to the exact date when the incentive at interest was instituted. In this case the most recent date is used in the models.

- Control Variables

The quarterly living standard data are from Accra Cost Of Living Index published by The Council For Community And Economic Research. These variables include gasoline price, apartment rent, home price, etc.

I also collected E85 price data over the past six years from DOE's Clean Cities Alternative Fuel Price Report. The E85 price data are recorded in seven regions in the report, namely New England, Central Atlantic, Lower Atlantic, Midwest, Gulf Coast, Rocky Mountain, and West Coast.

The demographics data were from the Annual issues of American Community Survey. These include population, proportion of different ethnicities (white, black, American Indian, Asian, and others), education levels (college and high school only), and income levels.

4.2 Number of FFVs Sold and Number of E85 Fueling Stations

Aggregating quarterly data of the number of FFVs sold in each MSA into annual data across the country, we see that the number of flex fuel vehicles sold demonstrates an increasing trend in the period in study (Figure 4-1). The number only dropped in 2008 largely due to the impact of financial crisis on the national economic environment. It has been increasing afterwards and the 2007 level was surpassed two years after in 2010. In 2012 FFVs sold has reached 1.5 million, almost four times that of four years ago in 2008.

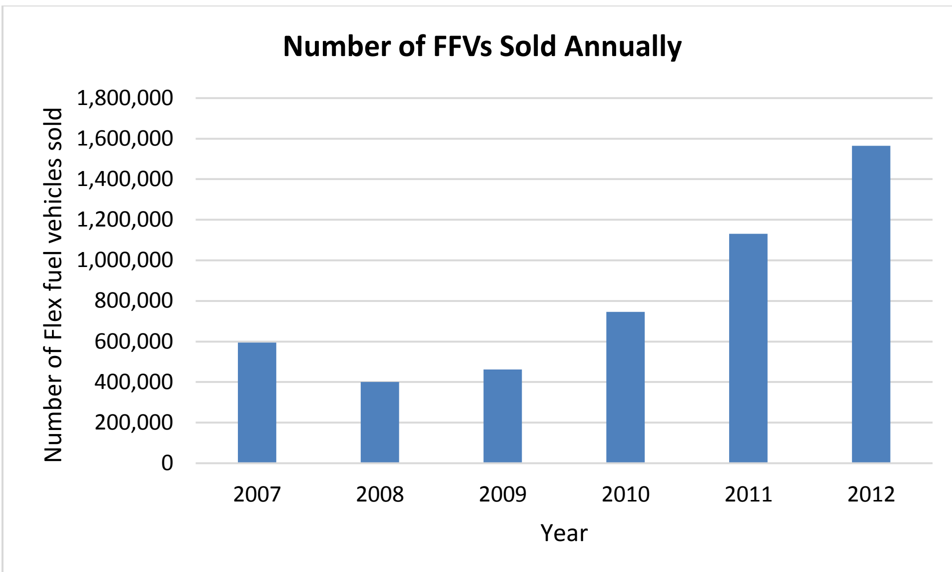

Figure 4-1. Annual Number of Flex Fuel Vehicles Sold

In the 2007 to 2012 period, Texas sold an average of 110,853 FFVs per year, ranking the highest among all states, while Delaware, with an average of 647 per year, ranks the lowest.

Annual average FFV shares demonstrate a similar trend – from Figure 4-2, we can see the increasing penetration of flex fuel vehicles in the consumer vehicles mix. The difference lies in 2009, when the number of FFVs sold was still lower than that of 2007 but its share in total new vehicles sold had surpassed the 2007 level.

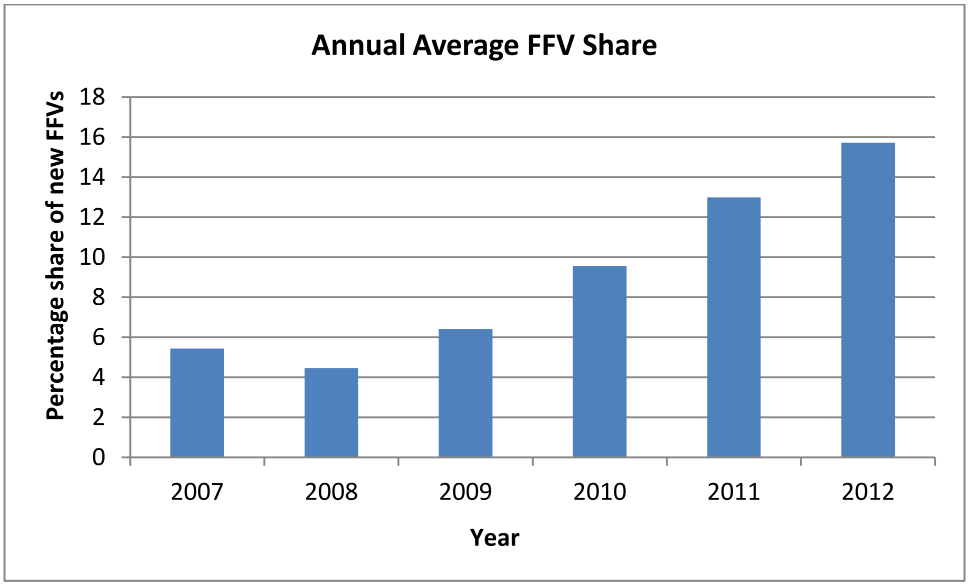

Figure 4-2. Annual Average FFV Share of All New Vehicles Sold

For the average share of FFVs sold among all types of new vehicles from 2007 to 2012, North Dakota ranks the highest with 24% share in FFVs. Hawaii on the other hand ranks the lowest with 3.4%. All of the typical Corn Belt states have average shares of more than 10%. Corn Belt states in the Midwest represent the most intensively agricultural region, connoting a lifestyle based on ownership of family farms, with supporting small towns and powerful farm organizations. They typically include Iowa, Illinois, Indiana, southern Michigan, western Ohio, eastern Nebraska, eastern Kansas, southern Minnesota and parts of Missouri.

From quarterly data on the number of new E85 fueling stations per million people for each MSA, I calculate the annual average number of E85 fueling stations per million people across the nation. As we can see from Figure 4-3, the station density has been increasing steadily across the country in the past six years, with the number in 2012 more than tripling that of 2007.

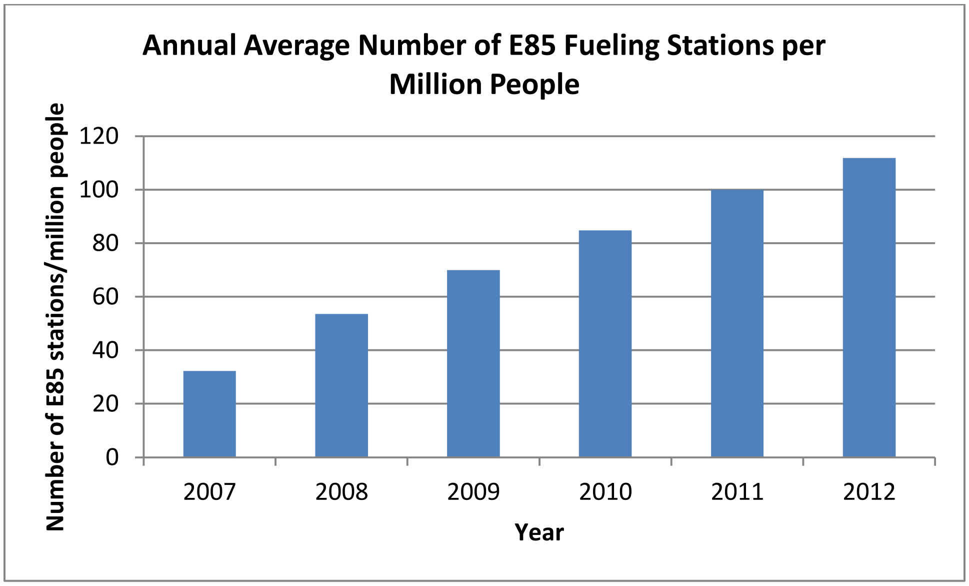

Figure 4-3. Annual Average Number of E85 Fueling Stations per Million People

Up until 2012, ten states didn't have any E85 fueling stations. Minnesota has the most E85 stations up to 2012.

In Figure 4-4 to Figure 4-15, I have created maps of MSAs showing different densities of FFV shares and E85 stations each year represented by varying shades of blue. In these maps, the MSAs are grouped into four categories; darker blue represents higher relative density of FFVs' penetration or E85 stations' distribution. For example, MSAs with the darkest blue represent the highest 25% of densities. We see that the darkest blue concentrate in the Midwest, and there's a clear trend of increasing boundary values for both FFVs' share and station density from 2008 to 2012.

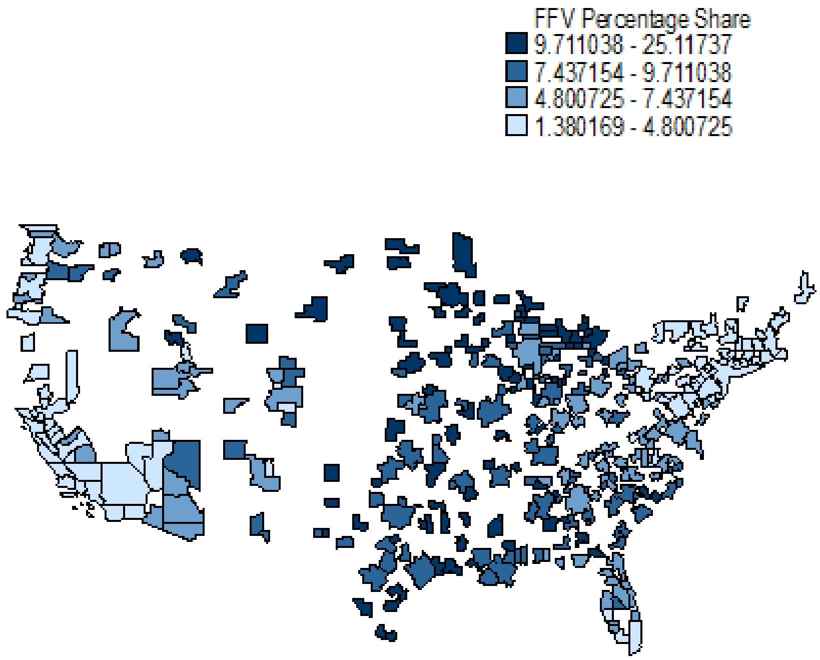

Figure 4-4. FFV Share in 2007 Q4

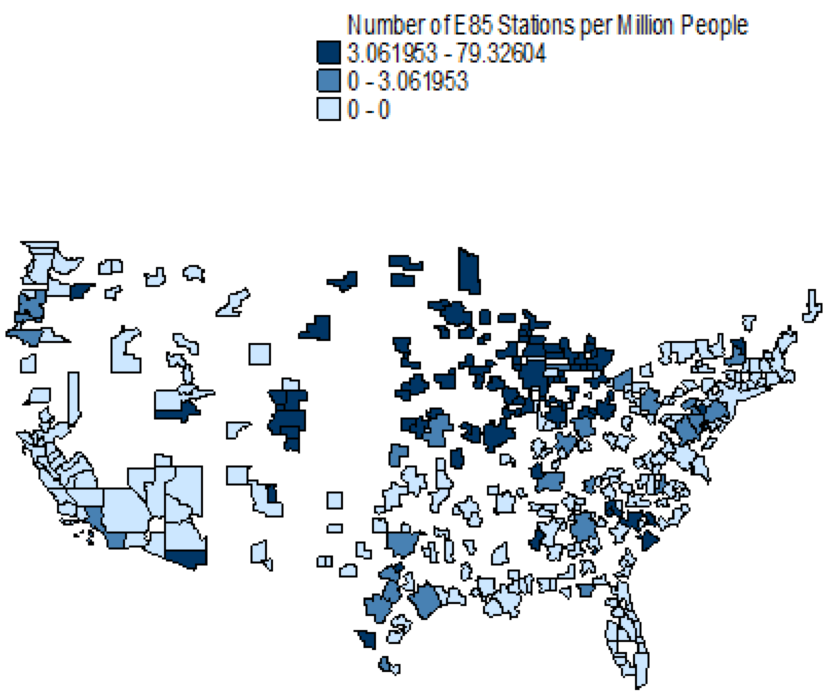

Figure 4-5. E85 Station Distribution in 2007 Q4

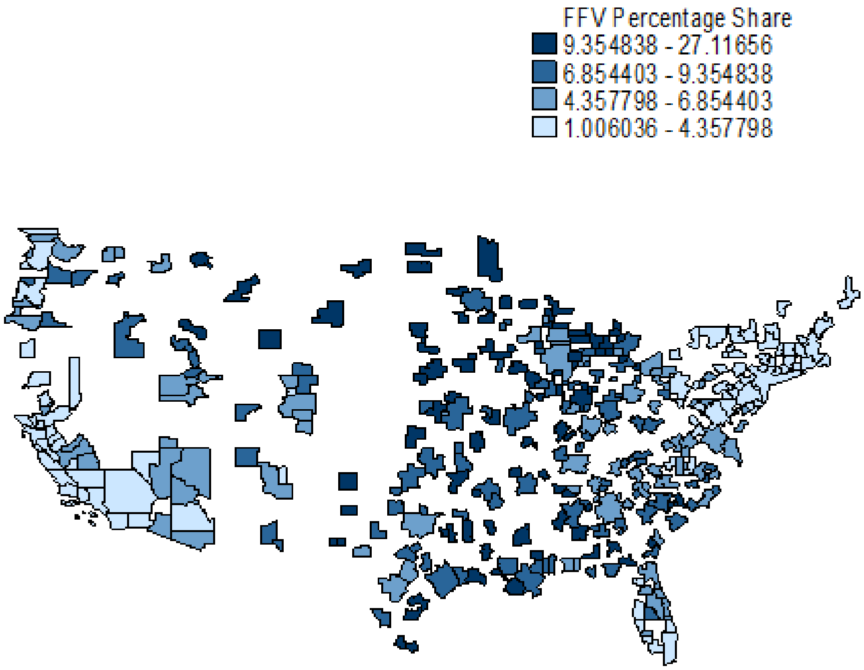

Figure 4-6. FFV Share in 2008 Q4

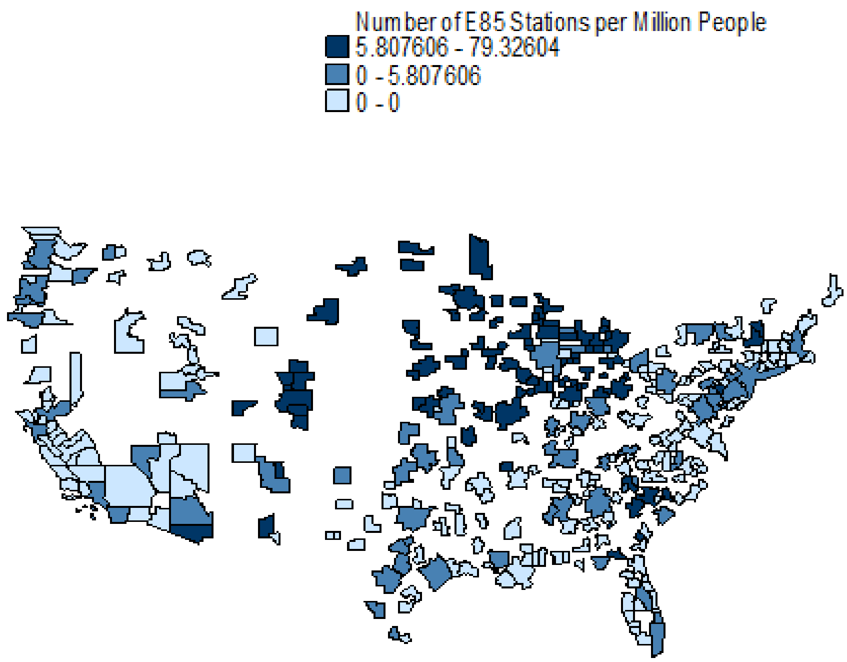

Figure 4-7. E85 Station Distribution in 2008 Q4

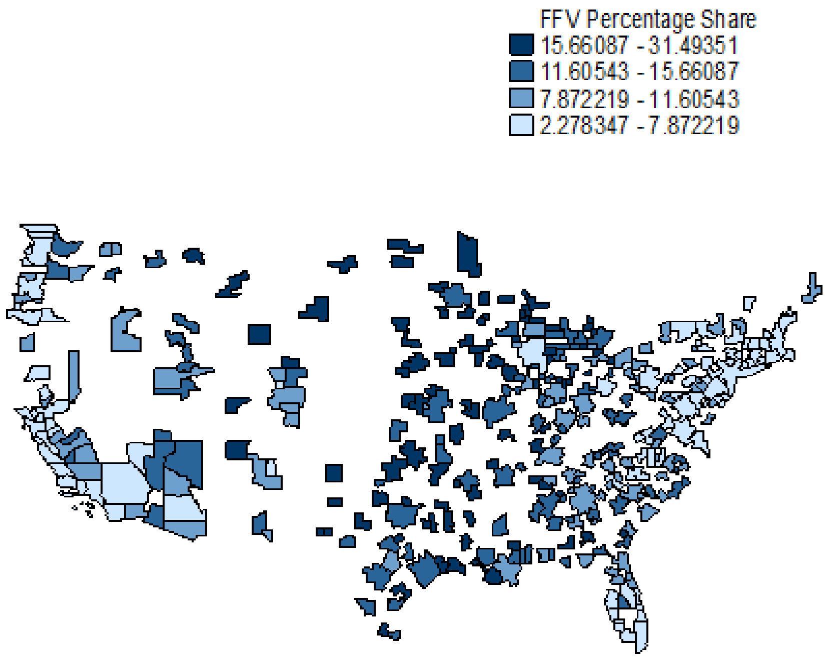

Figure 4-8. FFV Share in 2009 Q4

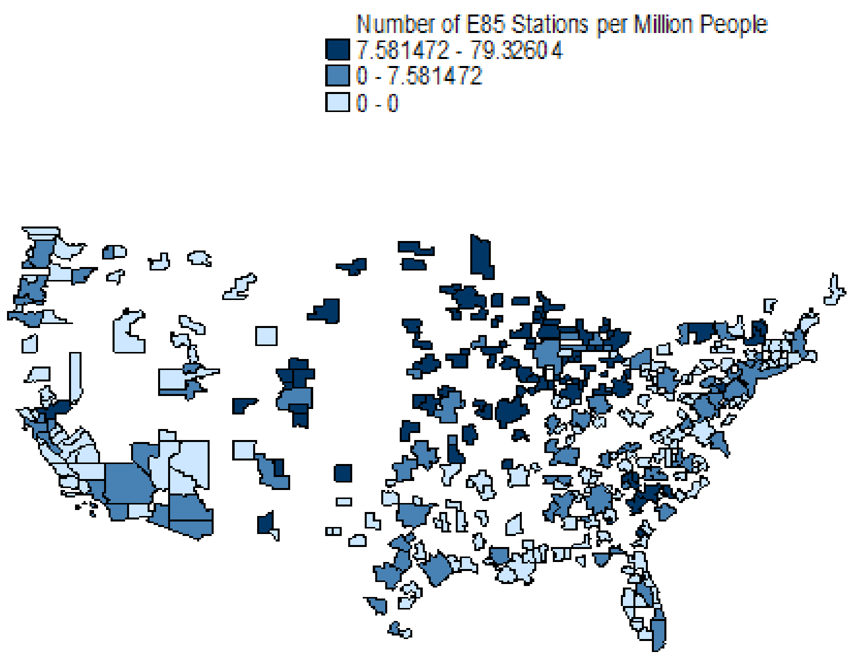

Figure 4-9. E85 Station Distribution in 2009 Q4

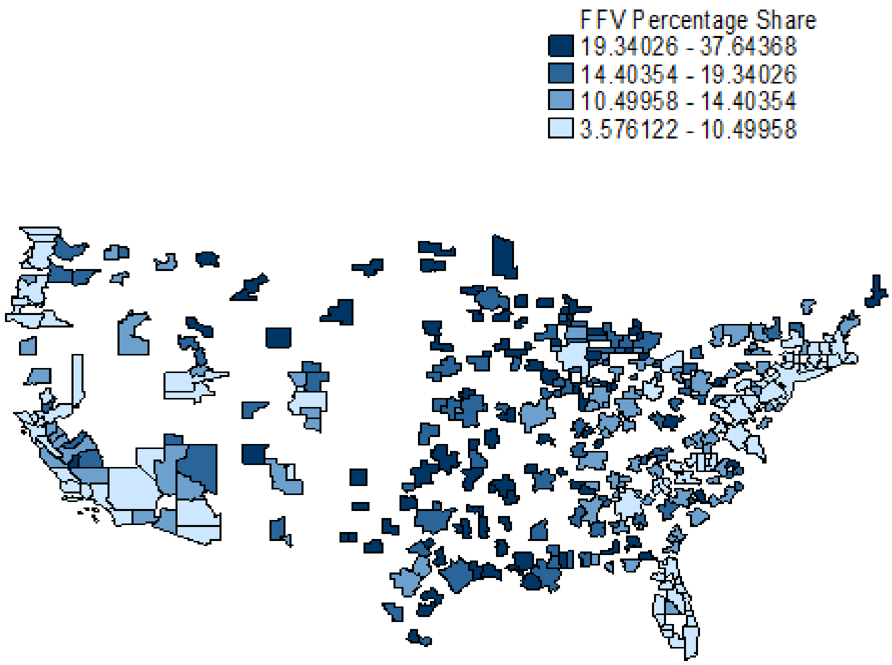

Figure 4-10. FFV Share in 2010 Q4

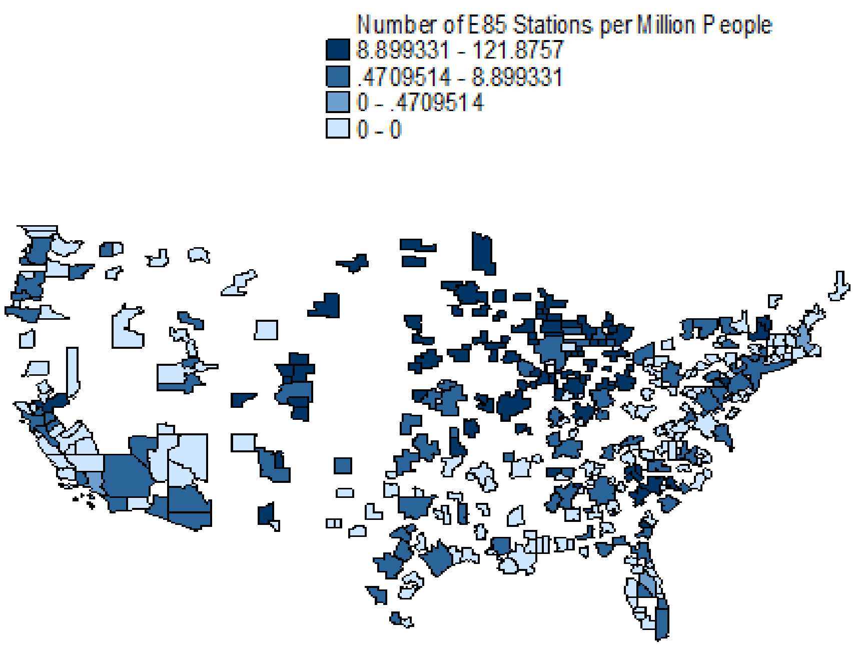

Figure 4-11. E85 Station Distribution in 2010 Q4

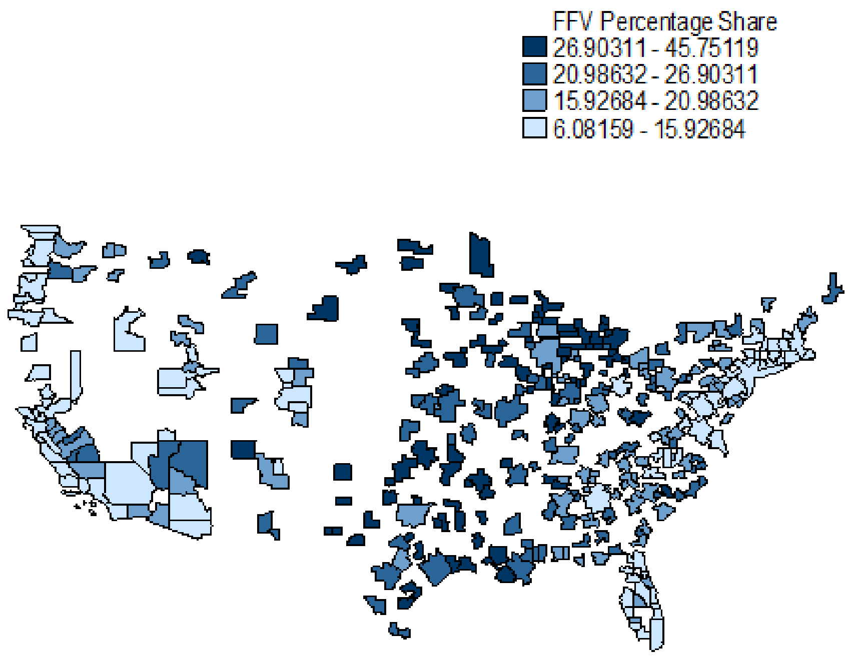

Figure 4-12. FFV Share in 2011 Q4

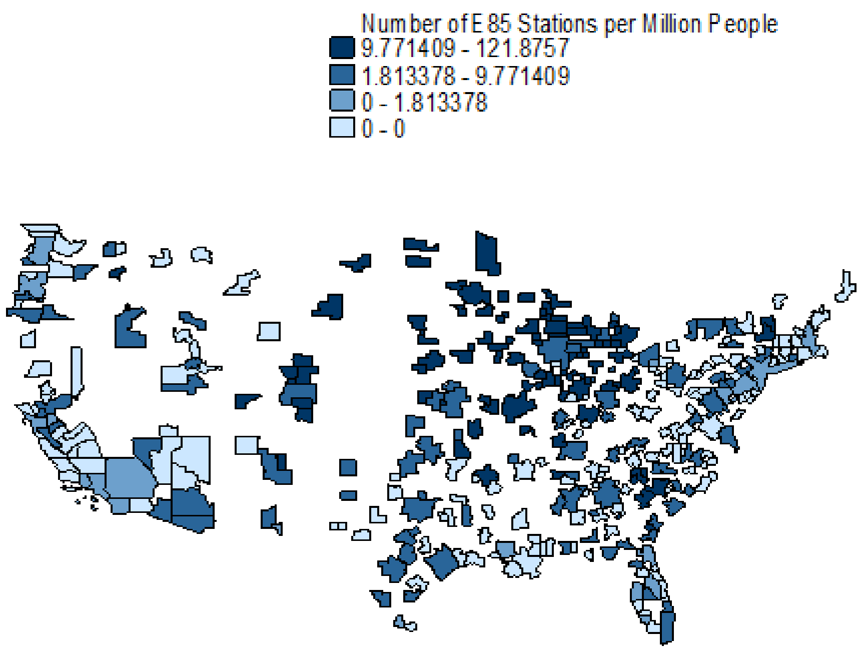

Figure 4-13. E85 Station Distribution in 2011 Q4

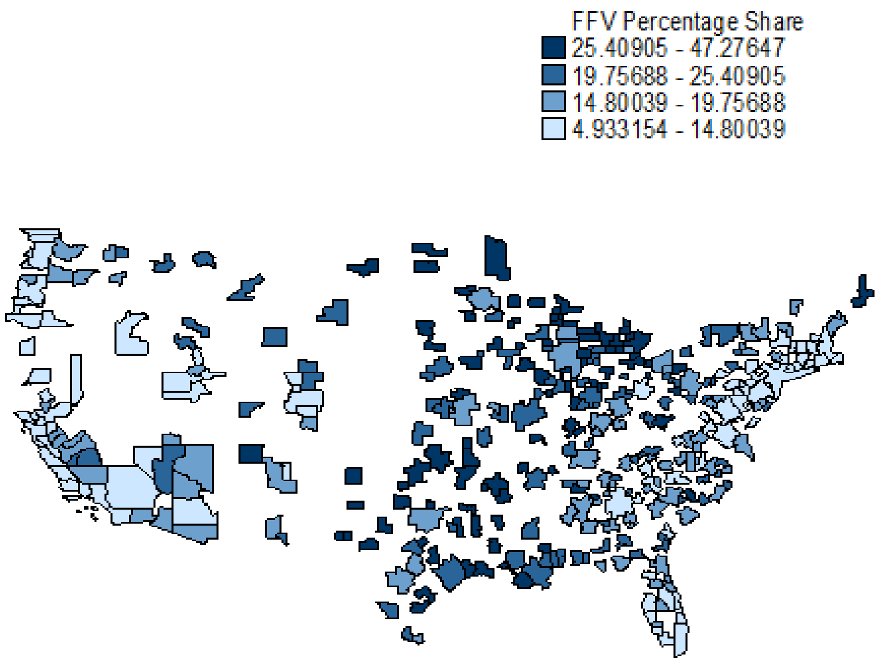

Figure 4-14. FFV Share in 2012 Q4

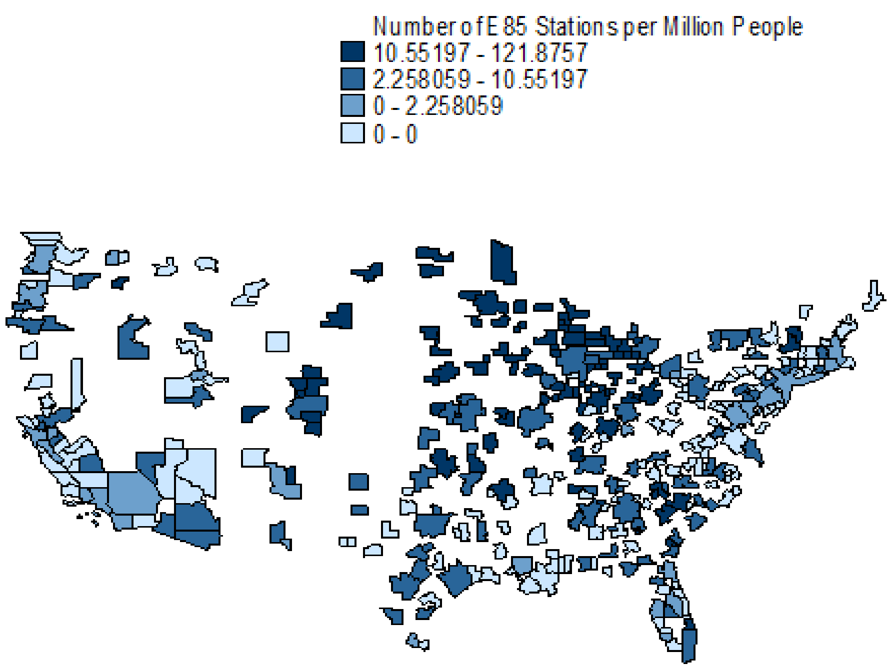

Figure 4-15. E85 Station Distribution in 2012 Q4

4.3 Control Variables

- Relative price of E85 vs. Gasoline

E85 price and gasoline price are potential factors in determining FFV demand. As simple economic demand and supply theory suggests, fuel price is expected to influence the demand for cars that use that fuel. Therefore the higher the price for the fuel E85 is compared to gasoline, ceteris paribus, the lower expected demand of flex fuel vehicles is. Since ethanol serves as a substitute for gasoline, when the price of gasoline goes up, demand for ethanol goes up and the price of ethanol would go up as well, which could lower FFV demand. Thus there's likely to be a negative relationship between gas price and FFV demand. Moreover high gasoline price shifts new auto purchases towards more fuel-efficient vehicles (Li, Timmins, and Haefen, 2009). As flex fuel vehicle is less fuel efficient than gasoline vehicles due to the energy content of ethanol, gasoline price should have an inverse relationship with FFV demand. This is indeed the case as seen in Appendix 2.

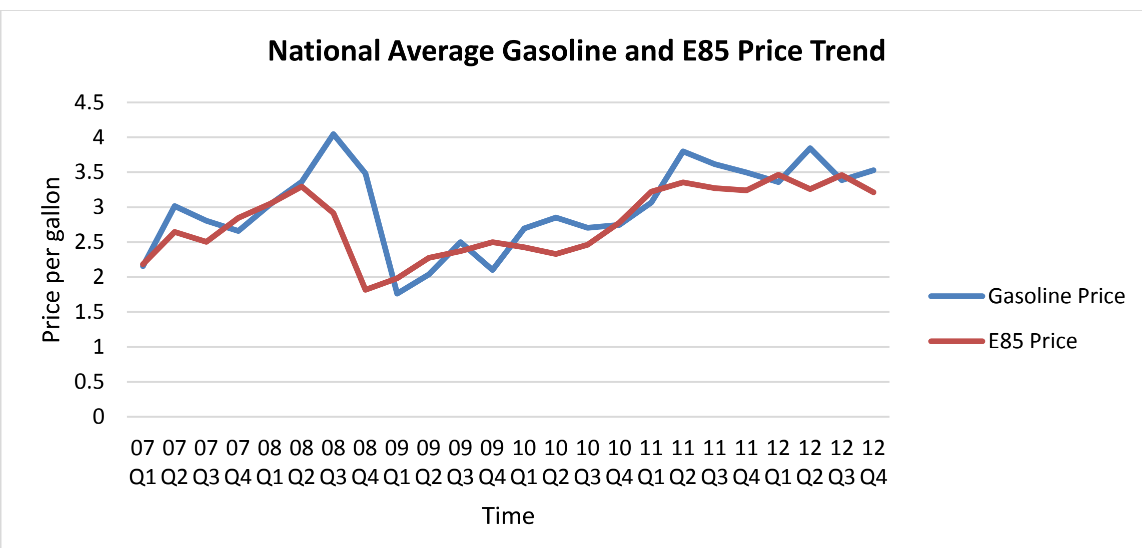

Figure 4-16. National Average Gasoline and E85 Price Trend

Figure 4-4 shows that the price of gasoline and E85 generally move together, with gas price a little higher than E85 price most of the time. The national average difference between the fuel prices is about 21 cents or 7% over the studied period.

- Time effects – Year and Quarter

Year effects may include the effects of federal incentives on FFV purchase, government economic and energy policies, and macroeconomic condition such as economic growth rate, population growth rate, and unemployment rate etc. Quarter effects may indicate seasonal fluctuations due to weather and business cycle.

- Income Effect

Income level indicates potential willingness to spend. Because of price difference between E85 and gasoline and the potential higher cost of FFV due to the per gallon energy difference between the two fuels, willingness to spend may impact whether consumers choose the more highly priced fuel or FFV.

- Travel Pattern

Data on travelling patterns include the average distance traveled by households and the proportion of each type of transportation means chosen by households. The average distance travelled using automobile by local households could be an indication of the different demand for different types of cars.

- Population Make-up

Population make-up including educational and ethnic background may also influence the decision to buy. The more educated people are, the more environmentally aware they might be and the more they may be willing to buy FFVs.

4.4 State Incentives

4.4.1 Incentives for FFV Consumers

State incentives for FFV consumers include incentives for purchasing or converting an FFV and for using alternative fuels, specifically E85. When purchasing an FFV, some states reward income tax credit. When converting to an FFV, some states offer tax credit, rebates, and some offer rebates specifically for school bus conversions. There are also states that offer purchase and conversion loans. To encourage the use of E85, some states offer rebates and some offer different kinds of tax exemptions.

- *Income tax credit*

To encourage purchase of FFV and converting existing vehicles to FFV, some states offer income tax credits. These states include Georgia, Kansas, Louisiana, and Montana.

In Georgia, income tax credit is available to individuals who purchase or lease a new dedicated AFV (Alternative Fuel Vehicle) or convert a vehicle to operate solely on an alternative fuel. The amount of the tax credit is 10% of the vehicle cost, up to $2,500. Qualified vehicles must meet emissions standards defined by the Georgia Board of Natural Resources. Any portion of the credit not used in the year the AFV is purchased or converted may be carried over for up to five years. This incentive was instituted in 2010, and assumed to be applicable in quarter 1 in the model.

In Kansas, an income tax credit is available for 40% of the incremental or conversion cost for qualified AFVs. The higher gross vehicle weight rating (GVWR), the larger credit there is. Up to $2400 credit is available for vehicles with less than 10,000 pounds of GVWR, up to $4000 is available for 10,000 to 26,000 lbs., and up to $40,000 is available for those over 26,000 lbs. Alternatively, a tax credit of 5% of the cost of the AFV, up to $750, is available for the purchase of an original equipment manufacturer AFV. To encourage purchase of new FFVs, this credit is allowed only to the first individual to take title of the vehicle. Taking into account that many consumers who own FFVs don't use alternative fuels because they are not fully aware of their vehicles' capabilities, the state specifies that for motor vehicles capable of operating on E85, the individual claiming the credit must provide evidence of purchasing at least 500 gallons of E85 between the time the vehicle was purchased and December 31 of the following calendar year. We would expect this incentive to not only increase the demand for FFV but also for E85 and therefore E85 fueling stations. Excess credits may be carried over for up to three years after the year in which the expenditures were made. This incentive was applicable after December 31, 1995 and beginning in 2013, the credit is only available to entities with corporate income tax liability. Since this incentive has been present throughout our studied period, it has no time variability and therefore eliminated from the models.

Louisiana offers an income tax credit of 50% of the cost of converting a vehicle to operate on an alternative fuel, and 50% of the incremental cost of purchasing an original equipment manufacturer dedicated AFV. AFVs must be registered in Louisiana to receive the tax credit. Alternatively, a taxpayer may take a tax credit of 10% of the cost of the motor vehicle, up to $3,000. This provision is in effect from July 9, 2009 to December 31, 2012.

In Montana, Businesses or individuals are eligible for an income tax credit of up to 50% of the equipment and labor costs for converting vehicles to operate using alternative fuels. The maximum credit is $500 for the conversion of vehicles with a GVWR of 10,000 lbs. or less, and $1,000 for vehicles with a GVWR of more than 10,000 lbs. The credit is only available during the year that the business or entity converts the vehicle. Montana Code which specifies this incentive is last amended in 2009, thus first quarter in 2009 is used as the starting date of this incentive.

As not all the above states have percentage or uniform maximum amount specifications, it's impractical to assign a single number to each state for comparison. Therefore I assign 1 to the above states during the period when the incentive is in effect, and 0 for the rest of the time and for all other states.

- *Tax Exemption*

States that offer tax exemption incentive for private FFV consumers are Massachusetts, Michigan, North Carolina, New York, and Wisconsin. North Carolina, New York, and Wisconsin have complete tax exemption provisions in their state laws regarding consuming E85, while Massachusetts allow for partial tax exemption and Michigan sets a restriction for cellulosic biofuel.

North Carolina states in its General Statutes that the retail sale, use, storage, and consumption of alternative fuels are exempt from the state retail sales and use tax. While this law is still active, North Carolina General Statutes didn't specify the starting date of this incentive.

According to New York Tax Law, E85 used exclusively to operate a motor vehicle engine is exempt from state sales and use taxes. The exemption is in effect from September 1, 2006 until September 1, 2014.

Wisconsin Statutes states that no county, city, village, town, or other political subdivision may levy or collect any excise, license, privilege, or occupational tax on motor vehicle fuel or alternative fuels, or on the purchase, sale, handling, or consumption of motor vehicle fuel or alternative fuels. The law was enacted in 1993 and is still in effect.

In Massachusetts, fuel consisting of cellulosic biofuel or a blend of gasoline and cellulosic biofuel is eligible for an exemption of the $0.21 per gallon fuel tax, in proportion to the percentage of the fuel content consisting of cellulosic biofuel. This exemption was implemented in January 2009, and is available through the 2017 tax year.

In Michigan, a tax of $0.12 per gallon is imposed on gasoline containing at least 70% ethanol (E70). This is a $0.07 discount compared to the conventional gasoline tax of $0.19 per gallon. This incentive was enacted in April 2001. Qualified AFVs are also exempt from personal property taxes. The exemption only applies to personal property that is new to Michigan. To be eligible, the vehicle must not have been previously taxed or exempted from taxation under another law. This law was enacted in 2002 and expired on December 31, 2012.

Even though there are five states that offer tax exemption incentive, only Massachusetts' incentive has time variability during our studied period.

- *Purchase Rebates*

Instead of or in addition to offering tax credit, some states offer rebates to encourage FFV adoption. States that have rebate incentives to consume E85 or to purchase FFVs include California and Illinois.

In California, the Fueling Alternatives vehicle rebate program is funded by the California Air Resources Board and provides grants of up to $5,000 to consumers who purchase or lease eligible AFVs between May 24, 2007, and April 30, 2009. In this case, second quarter 2007 is set as the starting point and first quarter 2009 is set as the terminating point of this incentive.

The Illinois Alternate Fuels Rebate Program provides a rebate for 80% of the incremental cost of purchasing an AFV (up to $4,000), 80% of the cost of converting a conventional vehicle to an AFV using a federally certified conversion (up to $4,000), and for the incremental cost of purchasing alternative fuels. A vehicle may receive one rebate in its lifetime. Only AFVs purchased from an Illinois-based company or vendor are eligible, except if the vehicle is a heavy-duty specialty vehicle that is not sold in Illinois. To qualify for a fuel rebate, the entity or individual must purchase the majority of E85 or biodiesel fuel from Illinois retail stations or fuel suppliers. The E85 fuel rebate is up to $450 per year (depending on vehicle miles traveled) for up to three years for each flexible fuel vehicle that uses E85 at least half the time. Rebates are part of the Illinois Green

Fleets Program and are available to all qualified Illinois residents, businesses, government units (except federal government), and organizations located in Illinois.

Since the two states have different provisions and specifications of the rebate incentive, it's hard to compare the difference between states due to different provisions of the incentive. Therefore rather than choosing a numerical number to assign to each state, I use dummy variable in order to just compare regions and periods of time where the incentive is in place and those that without.

- *Purchase Loans*

The Nebraska Energy Office administers the Dollar and Energy Saving Loan Program, which makes low-cost loans available for a variety of alternative fuel projects, including the replacement of conventional vehicles with AFVs; the purchase of new AFVs; the conversion of conventional vehicles to operate on alternative fuels; and the construction or purchase of a fueling station or equipment. The maximum loan amount is $750,000 per borrower, and the interest rate is 5% or less. The loan has been offered since August 19, 2009.

Oklahoma has a private loan program with a 3% interest rate for the cost of converting private fleets to operate on alternative fuels and for the incremental cost of purchasing an original equipment manufacturer AFV. The loan repayment has a maximum six-year period. The program guidelines were provided in January 2012.

- *Other incentives*

Some states have rebate incentives specifically for school buses. The Illinois Department of Education will reimburse any qualifying school district for the cost of converting gasoline buses to more fuel-efficient engines or to engines using alternative fuels.

In Washington D.C., certified clean fuel vehicles are exempt from time-of-day and day-of-week restrictions and commercial vehicle bans, if these vehicles are part of a fleet that operates at least 10 vehicles in an ozone nonattainment area, as defined by the Clean Air Act[1].

The two major categories of incentives for E85 fueling stations are grants and tax credit. 19 states have provisions of grants while four states have tax credit incentives for building E85 fueling stations.

4.4.2 Incentives for E85 Fueling Stations

- *Fueling infrastructure grants*

The Arizona Biofuel Conversion Program distributes grants to encourage the use of biofuels in the state and to promote the development of fueling infrastructure. Up to $75,000 is available to public and private entities for the incremental cost of projects that result in new or converted biofuel storage and dispensing equipment. The program ends on July 1, 2015.

[1] As school bus conversion rebate and driving restriction exemptions are only explicitly provided in one state, their predictive power is not meaningful enough. Due to possible collinearity problem, these variables are not included in the models.

The Colorado Corn Blender Pump Pilot Program provides up to $5,000 for each qualified station dispensing mid-level ethanol blends. Projects must meet the application requirements and receive approval from Colorado Corn and the Colorado Department of Oil and Public Safety. Funding is available for up to ten stations in the state.

The Renewable Fuel Infrastructure Program of Iowa provides financial assistance to qualified E85 retailers. Cost-share grants are available for up to 70% of the total cost of the project, up to $50,000, to upgrade or install new E85 infrastructure. Applicants may also qualify for supplemental incentives of up to 75% of the cost of improvements, up to $30,000, to upgrade or replace an E85 fueling dispenser that has not been approved by an independent testing laboratory. The supplemental incentive is available only to applicants who made the improvement no later than 60 days after the date of the publication in the Iowa administrative bulletin of the state fire marshal's order providing that a commercially available fueling dispenser is listed as compatible for use with E85 by an independent testing laboratory.

In Idaho, the Rural Idaho Economic Development Biofuel Infrastructure Matching Grant Fund provides grants for up to 50% of the cost of installing new fueling infrastructure dedicated to offering biofuels for retail sale, or for upgrading existing fueling infrastructure in order to be compatible with biofuels for the purpose of offering biofuels for sale. The Energy Division of the Idaho Department of Water Resources administers the Fund. This incentive expired on July 1, 2009.

In Indiana, the Flex Fuel Pump Program offers fuel retailers grants up to 50% or $20,000 (whichever is less) toward the purchase of a flex fuel pump, hardware and storage tank or the conversion of an existing pump to a blender pump. The program is open to both new and existing stations in Indiana.

The Illinois Department of Commerce and Economic Opportunity's Renewable Fuels Development Program is partnered with the Illinois Corn Marketing Board to fund new E85 fueling infrastructure at retail gasoline stations. The American Lung Association of Illinois-Iowa administers the grants for up to $5,000 of the total costs for converting an existing facility to dispense E85, or up to 30% of the cost to construct a new E85 fueling station or to modify a current station, with a maximum grant of $30,000 per facility.

The Kansas Corn Commission’s Blender Pump Program provides funding of $2,500 to offset infrastructure costs, plus $500 for promotion for qualified ethanol blender pump programs. Fuel stations that meet bonus criteria can receive up to $3,000 of additional funding. If bonus criteria is met, a fuel retailer can receive up to $6,000 in infrastructure and promotional funds. To be eligible, the applicant agrees to offer the following for a minimum time period of 12 months: E10 and E85 fuels along with two blends between E10 and E85.

The Maryland Grain Producers Utilization Board manages a Department of Energy Clean Cities Infrastructure Grant to develop E85 in the Virginia, Maryland and Greater Washington region. Funding is available for an E85 terminal in Maryland and/or up to ten E85 retail sites located in Maryland, Virginia and/or the District of Columbia on a 65% cost-share. Cost share must be from non-federal sources. For example, if a project costs $100,000, the grant would pay $35,000 and the recipient would pay the remaining $65,000. Highest priority will be given to an E85 terminal in Maryland. Second highest priority will be given to retail sites located along or near the I-95 corridor. Retail sites must be open to the public.

The Clean Energy Coalition in Michigan offers the Ethanol Blend Infrastructure Grant Program of up to $10,000 per facility for the cost of purchasing and installing fueling infrastructure necessary to dispense E85. New infrastructure as well as the conversion of existing infrastructure is eligible. Grants are available for retail and fleet fueling locations that are open to the public, and the infrastructure must be in place and available for use by December 31, 2013. The E85 Infrastructure Conversion Project (expired on December 31, 2009) provides funding to retail and public fleet fueling locations to purchase and install materials and equipment compatible with E85, to clean tanks, and to purchase dispensing equipment and on-site signage advertising E85. Funding of up to $5,000 per facility, not exceeding 50% of E85 conversion costs, was available through the Clean Energy Coalition. An earlier grant that expired on September 30, 2007 gave qualified service station owners and operators matching grants to convert existing, and install new, fuel delivery systems designed to provide E85 and biodiesel blends. Grants may not exceed 75% of the costs to convert existing fueling infrastructure, up to $3,000 per facility. Grants may not exceed 50% of the construction costs to install new fueling infrastructure, up to $12,000 per facility for E85 and $4,000 per facility for biodiesel blends. Other funding limitations may apply. E85 is defined as a fuel blend that contains between 70% and 85% denatured ethanol.

The Minnesota Clean Air Choice Team is offering funding assistance to fuel retailers for the installation of equipment to dispense E85 to the public. A qualified retailer may apply for a grant in the amount of 50% of eligible project costs. Funding may also be available to fuel retailers for the installation of ethanol blender pumps based on program priorities. Funding is limited and not guaranteed.

Missouri Corn provides $3,000 grant available to retailers who install flex pump infrastructure, $2,500 for infrastructure and $500 for promotional efforts.

Through a grant program, Nebraska Corn Board awards qualifying retailers $30,000 for the first pump and installation and $10,000 for the second pump. There is $40,000 maximum available per retail location for blender pumps. This money is available on a first-come, first-served basis until the money is exhausted. After that, retailers will be added to a waiting list. If additional funds become available, funding will be awarded in the order applications are received.

The New York State Energy Research and Development Authority (NYSERDA) administers the Biofuel Station Initiative Program, which provides funding to retail fueling stations offering E85 in the state, and to petroleum terminal operators to store, blend, and dispense biofuels. NYSERDA provides a reimbursement of up to 50% of new biofuel dispensing installation costs, including equipment, storage tanks, and associated piping equipment, up to $50,000 per site. NYSERDA also provides a cost reimbursement of up to 50% for new biofuel storage, handling, blending, and rack dispensing equipment, including installation costs, up to $150,000 per site. NYSERDA accepts applications from public access retail fueling station owners and operators in the state. Funding is limited and does not cover facility permitting or engineering costs. A 50% cost-shared technical assistance is also available for the following: technical review of design and construction specifications for the biofuel equipment; analysis of existing and proposed equipment; preparation and submission of requests for biofuel specific permits and waivers to local and state code officials; and facility staff training.

Through the Biofuels Blender Pump Program, the North Dakota Department of Commerce offers cost-share grants of up to $5,000 per fueling pump, up to $20,000 per retail location, to motor fuel retailers who install qualified biofuel blender pumps and associated equipment. Qualified retailers are also eligible for grants of up to $14,000 at each retail location for tanks and piping installed at the same time the blender pump is installed. A qualified ethanol retail blender pump must: 1) dispense a blend of gasoline and ethanol in the ratio the purchaser selects; 2) meet an industry standard and carry a warranty for compatibility with dispenser components and storage and piping systems; 3) have at least four hoses and dispense either a blend of 10% ethanol (E10) or the minimum blend percentage the U.S. Environmental Protection Agency has approved for use in all vehicles, a blend of at least 20 percent ethanol (E20), and E85; and 4) comply with all alternative fuel, biofuel, and flexible fuel requirements established by law. Grant recipients must continue to sell biofuel blends for at least 12 months after receiving funding. This incentive is available through April 30, 2013.

The Alternative Fuel Transportation Grant Program of Ohio provides grants and loans for up to 80% of the cost of purchasing and installing fueling facilities offering E85.

The Ethanol Infrastructure Incentive Program in South Dakota provides funding to offset the cost of installing ethanol blender pumps at retail fueling stations throughout the state. Awardees may receive $25,000 for the first pump installed and $10,000 for each additional pump, with a total of $950,000 in funding available for fiscal year 2012.

The California Energy Commission administers the Alternative and Renewable Fuel and Vehicle Technology program to increase the use of alternative and renewable fuels. Grants are available for the projects that include the expansion of fuel infrastructure, fueling stations and equipment.

The New Mexico Energy, Minerals, and Natural Resources Department administers the Clean Energy Grants Program, which provides grants for projects using clean energy technologies, including alternative fuel vehicles and fueling infrastructure, as well as projects that provide clean energy education, technical assistance, and training programs. These grants are provided on a competitive basis to qualifying entities such as municipalities and county governments, state agencies, state universities, public schools, post-secondary educational institutions, and Indian nations, tribes, and pueblos. As of March 2013, funding for this program is unavailable.

The Tennessee Department of Transportation (TDOT) engages in public-private partnerships with transportation fuel providers to install biofuel fueling facilities. Fueling facilities include storage tanks and fuel pumps dedicated to dispensing E85. TDOT administers the Biofuel Green Island Corridor Grant Project (Project) to provide financial assistance for purchasing, preparing, and installing fueling facilities at private sector fuel stations. The goal of the Project is to help establish biofuel stations within 100 miles of each other along Tennessee's interstate system and major highways. As of July 2012, there are no open grant solicitations.

The Tennessee Department of Environment and Conservation provides funding for alternative fueling infrastructure improvements through the FastTrack Infrastructure

Development Program. Private sector businesses may use funds to locate or expand fueling infrastructure in the state.

The Texas Commission on Environmental Quality administers the Emissions Reduction Incentive Grants (ERIG) Program, part of the Texas Emissions Reduction Plan, which provides grants for various types of clean air projects to improve air quality in the state's nonattainment areas. Eligible projects include those that involve alternative fuel dispensing infrastructure.

- *Fueling infrastructure tax credit*

Income tax credit is available in Idaho for qualified biofuel fueling infrastructure. The credit is 6% of the cost to install new, or upgrade existing, fueling infrastructure for the purpose of selling and dispensing biofuel. The allowable credit cannot exceed 50% of the taxpayer's income tax liability. For the purpose of this incentive, biofuel is defined as any fuel offered for sale as a transportation fuel that is agriculturally derived and meets applicable ASTM standards, including, but not limited to, ethanol, ethanol blended fuels, biodiesel, and biodiesel blended fuels. This incentive expires after December 31, 2011.

In Kansas, an income tax credit is available for 40% of the total cost to install alternative fueling infrastructure after January 1, 2009. Qualified property must be directly related to the delivery of alternative fuel into the fuel tank of a motor vehicle propelled by such fuel. The tax credit may not exceed $100,000 per fueling station. Excess credits may be carried over for up to three years after the year in which the expenditures were made. Beginning in 2013, the credit is only available to entities with corporate income tax liability.

Louisiana offers an income tax credit of 50% of the cost of alternative fueling equipment. AFVs must be registered in Louisiana to receive the tax credit.

The Michigan Department of Energy, Labor and Economic Growth (DELEG) offers an income tax credit to fueling station owners who convert existing fuel delivery systems or install new systems to provide E85 or biodiesel blends to the public. The tax credit is for 30% of the eligible costs of an installed or converted fuel delivery system with a maximum tax credit of $20,000 per applicant. To qualify, a station owner must apply for a certificate of eligibility from DELEG and provide documentation for the equipment purchased. Each installation will be inspected to ensure all work has been completed and E85 or biodiesel is being dispensed to the public. Any federal and state grants and incentives the station owner receives will be subtracted from the cost of the project before computing the amount of the tax credit. Federal tax credits do not need to be subtracted when determining the tax credit amount. The tax credit is available for projects completed between January 1, 2009, and December 31, 2011.

In New York, state tax credit is available for alternative fuel vehicle fueling infrastructure installed in the state. The tax credit is equal to 50% of the infrastructure cost. This includes infrastructure for storing or dispensing an alternative fuel into a motor vehicle's fuel tank, as well as infrastructure used for charging electric vehicles. Eligible alternative fuels include natural gas, liquefied petroleum gas, hydrogen, electricity, and any other fuel that is a least 85% ethanol or other alcohol. This credit expired December 31, 2010.

Through the Residential Energy Tax Credit program in Oregon, qualified residents may receive a tax credit for 25% of alternative fuel infrastructure project costs, up to $750. A company that constructs a dwelling in Oregon and installs fueling infrastructure in the dwelling may claim the credit. All qualified infrastructure must be installed to meet all state and local codes and be capable of fueling or charging an alternative fuel vehicle within 14 hours. This credit is available through December 31, 2017.

Business owners and others may be eligible for a tax credit of 35% of eligible costs for qualified alternative fuel infrastructure projects. Unused credits can be carried forward up to five years. Non-profit organizations and public entities that do not have an Oregon tax liability may receive the credit for an eligible project but must "pass-through" or transfer their project eligibility to a pass-through partner in exchange for a lump-sum cash payment. The Oregon Department of Energy determines the rate that is used to calculate the cash payment. The pass-through option is also available to a project owner with an Oregon tax liability who chooses to transfer their tax credit. The credit is available through December 31, 2018.

In Wisconsin, a tax credit is available for 25% of the cost to install or retrofit fueling pumps that dispense E85 or that mix fuel from separate storage tanks and allow the user to select the percentage of renewable fuel. The maximum credit amount is $5,000 per taxable year for each fueling station that has installed or retrofitted a pump. The credit must be claimed within four years of the tax return and expires December 31, 2017.

- *Purchase, conversion, and fueling infrastructure loans*

Provisions of loans are generally inclusive of both consumers and fueling station owners, with similar terms.

The Nebraska Energy Office administers the Dollar and Energy Saving Loan Program. The Program makes low-cost loans available for a variety of alternative fuel projects, including the replacement of conventional vehicles with AFVs; the purchase of new AFVs; the conversion of conventional vehicles to operate on alternative fuels; and the construction or purchase of a fueling station or equipment. The maximum loan amount is $750,000 per borrower, and the interest rate is 5% or less.

The Virginia Board of Education may use funding from the Literary Fund to provide loans to school boards that convert school buses to operate on alternative fuels or construct alternative fueling stations.

4.4.3 <u>Incentives for Government Fleets</u>

- *Tax Exemption*

Delaware Code specifies that taxes imposed on alternative fuels used in official vehicles for the United States government or any Delaware state government agency, including volunteer fire and rescue companies, are waived.

In New Mexico, alternative fuel distributed by or used for U.S. government; state government; or Indian nation, tribe, or pueblo purposes; is exempt from the state excise tax.

- *Purchase Rebates*

Propel Fuels, a company based in California that operate clean fuel stations offering alternative fuels, offers a rebate to qualified fleet customers for monthly purchases of more than 500 gallons of biodiesel blends and E85. Fleet customers must purchase the fuel directly from Propel public retail locations using the Propel CleanDrive Wright Express fleet card. The program offers a rebate of $0.03 per gallon for purchases of less than 1,000 gallons of biofuel per month, and $.05 per gallon for purchases of 1,000 gallons or more per month. The rebate is applied at the end of each monthly billing cycle.

In Indiana, A political subdivision that purchases E85 for use in flexible fuel vehicles (FFVs) may be entitled to a monthly E85 incentive payment of $33.33 for each FFV that has been owned by the political subdivision for less than five years. To be eligible, 75% of the political subdivision's fuel purchases in the preceding month must be E85 for use in FFVs. A political subdivision is defined as a municipal corporation or special taxing district. This incentive expires January 1, 2015.

The North Carolina State Energy Office administers the Energy Policy Act (EPAct) Credit Banking and Selling Program, which enables the state to generate funds from the sale of EPAct 1992 credits. The funds that EPAct credit sales generate are deposited into the Alternative Fuel Revolving Fund (Fund) for state agencies to offset the incremental costs of purchasing E85, developing alternative fueling infrastructure, and purchasing AFVs. Funds are distributed to state departments, institutions, and agencies in proportion to the number of EPAct credits generated by each. The Fund also covers additional projects approved by the Energy Policy Council.

The Alternative Fuel Transportation Grant Program in Ohio provides funding for up to 80% of the incremental cost of purchasing and using alternative fuel for businesses, nonprofit organizations, public school systems, and local governments.

- *Loans*

The Oklahoma Department of Central Services' Alternative Fuels Conversion Loan program provides 0% interest loans to government fleets for converting vehicles to operate on alternative fuels, the construction of AFV fueling infrastructure, and the incremental cost associated with the purchase of an original equipment manufacturer AFV. The program provides up to $10,000 per converted or newly purchased AFV and up to $300,000 for the development or installation of fueling infrastructure. The borrower must repay the loan within a seven-year period. Repayment is collected through a surcharge on alternative fuel the borrower purchased in the amount equivalent to the per gallon fuel cost savings from using an alternative fuel. If the price of the alternative fuel does not remain below the price of the conventional fuel that it replaced, repayment is suspended. Eligible applicants include state and county agencies and divisions, municipalities, school districts, mass transit authorities, and public trust authorities.

Since only one state has government fleet purchase loans, it’s not included as a separate instrument in the IV regressions.

4.4.4 Summary

I include types of state incentives that are used in the models in Table 4-1, excluding incentives that are unique to the specific state[2] and those that are too generalized or vague[3]. Also since I'm only interested in incentives that affect new FFV purchase (as the data contains only new vehicle purchases), conversion cost rebate and conversion tax credit incentives that promote of conversion of an owned vehicle to an FFV are also excluded from the models.

[2] Referring to driving restriction exemption in Washington D.C.

[3] Referring to states that have no specifications, amount or dates of incentive provisions.

Table 4-1 State Incentive Distributions

	Consumer incentives				Government fleet incentives		Station incentives	
	Income Tax Credit	Tax Exemption	Purchase Rebate	Purchase Loans	Purchase Rebate	Tax Exemption	Rebate	Tax Credit
Alaska								
Alabama								
Arkansas								
Arizona							*	
California			*		*			
Colorado							*	
Connecticut								
District of Columbia								
Delaware						*		
Florida								
Georgia	*						*	
Hawaii								
Iowa							*	
Idaho							*	*
Illinois								
Indiana					*		*	
Kansas							*	*
Kentucky								
Louisiana	*							*
Massachusetts		*						
Maryland							*	
Maine								
Michigan							*	*
Minnesota								
Missouri							*	

Mississippi								
Montana	*							
North Carolina					*			
North Dakota							*	
Nebraska				*			*	
New Hampshire								
New Jersey								
New Mexico						*	*	
Nevada								
New York							*	*
Ohio								
Oklahoma				*				
Oregon								
Pennsylvania								
Rhode Island								
South Carolina								
South Dakota							*	
Tennessee							*	
Texas								
Utah								
Virginia								
Vermont								
Washington								
Wisconsin								*
West Virginia								
Wyoming								

Note: * indicates time variability; the incentive in the marked state either was implemented after 1st quarter 2007 or expired before 4th quarter 2012.

As we can see from Table 4-1, 30 states have some type(s) of incentive variables assigned to them. Of these, 13 have consumer incentive variables, of which 7 states either instituted the incentive after 2006 or terminated before 2012 or both, and 6 states have seen the incentives in place for the period throughout 2007 to 2012. For the purpose of examining the effects of different incentives across time, variability during the studied time period is essential. Therefore only states with variable incentives contribute to the studied effects and are actually meaningful in the study. Among states that offer consumer incentives, three states have variable income tax credit, totaling 22 MSAs, two states have variable purchase loans, with a total of 5 MSAs, and one state each offers tax exemption and purchase rebate incentive. This means that the estimated effect of tax exemption is only based on its effectiveness in Massachusetts and the estimated effectiveness of purchase rebate is only based on the outcome of the incentive in California. While California has 26 MSAs, Massachusetts only has 5, including one that’s across borders extending to New Hamshire (Boston-Cambridge-Quincy).

5 Models

Fixed effects and random effects models are the most commonly used methods for panel data. If there are omitted variables, and these variables are correlated with the variables in the model, then fixed effects models may provide a means for controlling for omitted variable bias. In a fixed-effects model, subjects serve as their own controls. The idea is that whatever effects the omitted variables have on the subject at one time, they will also have the same effect at a later time; hence their effects will be constant, or “fixed.” However, in order for this to be true, the omitted variables must have time-invariant values with time-invariant effects. By time-invariant values, we mean that the value of the variable does not change across time. Gender and race are obvious examples. By time-invariant effects, we mean the variable has the same effect across time, e.g. the effect of gender on the outcome at time 1 is the same as the effect of gender at time 5. In addition, there needs to be within-subject variability in the variables if we are to use subjects as their own controls.

If there are no omitted variables – or if the omitted variables are uncorrelated with the explanatory variables that are in the model – then a random effects model is better. It will produce unbiased estimates of the coefficients, use all the data available, and produce the smallest standard errors. More likely, however, is that omitted variables will produce at least some bias in the estimates.

Instrumental Variables estimation is used when the model has endogenous variables. IV can thus be used to address the following important threats to internal validity:

- Omitted variable bias from a variable that is correlated with an explanatory variable but is unobserved, so cannot be included in the regression;
- Simultaneous causality bias (endogenous explanatory variables; explanatory variable causes explained variable and explained variable causes explanatory variable);
- Errors-in-variables bias (explanatory variable is measured with error)

Instrumental variables regression can eliminate bias from these three sources.

- *Fixed-effects Linear Model*

I use fixed effects model because I'm only interested in analyzing the impact of variables that vary over time – the impact of changing incentives and number of fueling stations on FFV demand. Fixed effects models explore the relationship between the predictor and the outcome variables within each MSA. Since each MSA has its own individual characteristics that may influence the predictor or outcome variables, there might be correlation between individual MSA's error term and the predictor variables. We need to control for this in order to assess the predictors' net effects. Using fixed effects model is appropriate as it removes the effects of the time-invariant characteristics from the predictor variables.

The fixed effects model assumes that local heterogeneity is captured by the intercept term, which means every MSA gets its own intercept α_i while the slope coefficients are the same. It also means that the heterogeneity is associated with the regressors on the right hand side.

The model's basic model form is

$$\text{FFV\_share}_{it} = \beta_0 + \beta_1 \text{ E85\_station\_}_{i(t-1)} + \beta_2 (\text{gas\_E85\_price\_ratio}_{it)}) + \beta_4 (\text{income\_tax\_credit}_{it)}) + \beta_6 (\text{purchase\_rebate}_{it)}) + \beta_5 (\text{tax\_exemption}_{it)}) + \beta_7 (\text{purchase\_loan}_{it)}) + \beta_8 (\text{year1\_dummy}) + \ldots + \beta_{14} (\text{quarter1\_dummy}) + \ldots + \beta_{18} (\text{log\_income}) + \beta_{19} (\text{log\_travel}) + \beta_{20} (\text{auto\_perc}) + \beta_{21} (\text{college\_perc}) + \beta_{22} (\text{white\_perc}) + \sum_{i=1}^{n} \delta_i \, T_i + u_{it}$$

The dependent variable is FFVs' share, subscript i represents MSA and t represents time from 1 to 24. The independent variables central to this paper are the number of E85 fueling stations and state incentives for FFV consumers. Their effects indicate whether and how FFV demand is responsive to building more E85 fueling stations and policy incentives for consumers. Year dummies, quarter dummies, and various population characteristic variables are added as control.

- *Random-effects tobit model*

The random effects model assumes that the individual effects are captured by the intercept and a random component μ_i. This random component is not associated with the regressors on the right hand side or part of the error term. The intercept becomes $\alpha + \mu_i$. While fixed effects models already have individual MSA's effects taken into account, tobit models don't have the MSA fixed effects (the effects are random).

Since the value of the dependent variable – the share of number of flex fuel vehicles sold – can't take values below zero, this is a regression with a censored dependent variable. With tobit model, I estimate the effects of E85 fueling stations and state incentives with left-censoring on FFV shares at 0. The data generating process can be described as:

$$FFV\_share_{it} = \max \{FFV\_share^{*}_{it}, 0\},$$

where

$$FFV\_share^{*}_{it} = \beta_0 + \beta_1\, E85\_station\_{i(t-1)} + \beta_2\, (gas\_E85\_price\_ratio_{it)}) + \beta_4\, (income\_tax\_credit_{it)}) + \beta_6\, (purchase\_rebate_{it)}) + \beta_5\, (tax\_exemption_{it)}) + \beta_7\, (purchase\_loan_{it)}) + \beta_8\, (year1\_dummy) + \ldots + \beta_{14}\, (quarter1\_dummy) + \ldots + \beta_{18}\, (log\_income) + \beta_{19}\, (log\_travel) + \beta_{20}\, (auto\_perc) + \beta_{21}\, (college\_perc) + \beta_{22}\, (white\_perc) + \sum_{i=1}^{n} \delta_i\, T_i + \alpha_i + u_{it}$$

α_i represents the individual effect and it's assumed that u_{it} is i.i.d., N(0, σ_{α}^{2}), and independent of α's.

- *Fixed-effects IV*

The demand for FFVs may have an effect on the number of E85 fueling stations, as Corts demonstrated specifically for government fleet FFV demand (Corts, 2010). To take this reverse causality into account, I use state incentives for E85 fueling stations as instrument for the number of E85 fueling stations, because the purpose of these incentives is to increase the investment in building E85 fueling stations. In addition these incentives don’t have a direct relationship with the demand for FFVs. As described in the above section, these incentives include fueling station grants, tax credit, and loans. The variable fueling station loan is only applicable to two states, thus it’s omitted in the models due to collinearity.

The validity of fueling station grants and fueling station tax credit as separate instruments is tested using Sargan Statistic. In Sargan test, the null hypothesis is that the selected instruments are valid. If the test statistic is small enough to reject the null, it means the separate instruments might not be valid. In this case, which is the case here, I use first-stage regressions of the station incentive variables on the number of stations. In order to account for the lagged E85 stations used in the models, the incentives for stations are also lagged for the same amount of time as that of the E85 station (one quarter in the model with one quarter lagged E85 station and one year in the model with the four quarter lagged variable of E85 stations). Since it takes time for the stations to be built, there could be a lag between an incentive is implemented and the new station is completed. I include one quarter and two quarter lags of these station incentives as instruments.

To find out whether E85 stations last quarter can predict FFV demand now, I combine the two incentives into one station incentive variable and test for its effectiveness as the instrument. The first-stage regression of the endogenous E85 station variable lagged for one quarter on the instrument station incentives lagged for two quarters and three quarters have R^2 values of 0.27 and 0.26 respectively. These R^2 values indicate weak effects of the combined stations incentives on the number of stations, which means that the station incentives variable is a weak instrument on number of stations. The estimated results from the first-stage regressions can be found in Appendix 1.

6 Results

Estimation results are presented in Table 6-1. The full table of results including control variables can be found in Appendix 2.

Table 6-1. Estimation Results

	(1) ffv_share	(2) ffv_share	(3) ffv_share	(4) ffv_share	(5) ffv_share	(6) ffv_share	(7) ffv_share	(8) ffv_share
main								
E85_Stat~1	0.0476**	0.0750***		0.0984***		0.149***	0.193***	0.121**
	[0.0165]	[0.0214]		[0.00859]		[0.0411]	[0.0448]	[0.0419]
gas_e85	-1.210***	-1.263***	-1.075***	-1.246***	-1.057***	-1.212***	-1.181***	-1.231***
	[0.0930]	[0.0969]	[0.103]	[0.180]	[0.180]	[0.182]	[0.184]	[0.182]
Tax_Credit	0.800	2.042*	2.011*	2.163***	2.124***	2.185***	2.270***	2.130***
	[0.671]	[0.865]	[0.876]	[0.251]	[0.248]	[0.268]	[0.272]	[0.268]
Rebate_P~e	1.605**	1.568**	1.064*	1.529***	1.057***	1.413***	1.321***	1.473***
	[0.559]	[0.531]	[0.481]	[0.227]	[0.224]	[0.249]	[0.253]	[0.249]
Loan_Pur~e	1.461*	1.140**	1.129**	1.326*	1.327*	0.962	0.855	1.030
	[0.620]	[0.343]	[0.385]	[0.548]	[0.544]	[0.563]	[0.569]	[0.562]
Tax_Exem~n	-1.951***	-1.586***	-1.442***	-0.707*	-0.629*	-1.334***	-1.184**	-1.431***
	[0.350]	[0.401]	[0.428]	[0.313]	[0.304]	[0.370]	[0.378]	[0.370]
E85_Stat~4			0.0686***		0.0884***			
			[0.0203]		[0.00753]			
_cons	22.97***	-29.49	-38.28	8.916	0.977			
	[0.285]	[19.86]	[19.79]	[9.859]	[9.729]			
sigma_u								
_cons				3.629***	3.652***			
				[0.176]	[0.179]			
sigma_e								
_cons				2.321***	2.341***			
				[0.0216]	[0.0213]			
N	8418	6118	6384	6118	6384	6118	6118	6118

Standard errors in brackets
* p<0.05, ** p<0.01, *** p<0.001

Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	No	No	Yes	Yes	Yes
State Fixed Effects	No	No	No	Yes	Yes	No	No	No
Other Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note:

1. Year 2012 and Quarter 4 are omitted from all models due to collinearity.
2. Other Controls include log income, log travel, auto proportion, college proportion, and white proportion.
3. Instruments for regression (6) are $fueling\_station\_grant_{t-1}$, $fueling\_station\_tax\_credit_{t-1}$, $government\_fleet\_puchase\_rebate_{t-2}$, and $government\_fleet\_tax\_credit_{t-2}$. Instruments for regression (7) are $fueling\_station\_grant_{t-2}$, $fueling\_station\_tax\_credit_{t-2}$, $government\_fleet\_puchase\_rebate_{t-3}$, and $government\_fleet\_tax\_credit_{t-3}$.

Models (1) to (3) present the fixed effects linear model that does not account for the endogeneity of E85 stations or the censoring of the dependent variable. Models (1) and (2) uses E85 stations lagged for one quarter as independent variable. Model (1) includes year and quarter fixed effects as additional control, model (2) further includes additional controls. Model (3) uses E85 stations lagged for 4 quarters for comparison reasons. It takes into account all controls including year, quarter, and other controls. All seven models examine the effects of tax credit, purchase rebate, purchase loans, and tax exemption on FFV share.

Models (4) and (5) present the results of the random effects tobit model, which account for the censoring of the dependent variable but not the endogeneity of E85 stations. Model (4) has E85 stations lagged for one quarter as independent variable, and model (5) has E85 stations lagged for one year. Both regressions include year and quarter fixed effects and other characteristics as controls.

Except for model (1) where the significance level for E85 stations is 10%, all other models achieve the 1% level of significance for the independent variable. For both fixed-effect and random-effects tobit models, the effect of E85 stations density in the last quarter is greater than that of the same quarter one year ago, taking into account the same control variables. This indicates that the availability of E85 stations in the nearer term – last quarter, has more predicative power compared to that of last year does. For fixed-effects models, the coefficients' difference is 0.007%, and for random-effect models the difference is 0.01%. This means that the effect of E85 station density at time t diminishes with the pass of time – greater than for time t+1 than for t+4. This means that consumers make purchasing decisions based on most recent available information on the availability of the fuel. In addition, this observation indicates that consumers make decisions rather quickly, which could be because of the readily available and easily accessible information on E85 stations. As such, for IV models I only use one-quarter lagged E85 station density as independent variable.

Regressions (6), (7), and (8) present results from the fixed effects IV models, which accounts for the endogeneity of E85 stations. Only E85 stations lagged for one quarter is considered because it's more relevant in determining consumer demand for FFV now. As described in Chapter 4.1, I include government fleet incentives and fueling station incentives as instruments in the IV models. All these regressions include all controls listed for previous models.

In regression (6), the IV used are two government incentive variables (government fleet purchase rebates and government fleet tax exemption) lagged for two quarters, and two station incentive variables (fueling station grant and fueling station tax credit) lagged for one quarter. For comparison, model (7)'s instruments include government incentive variables lagged for three quarters and station incentive variables lagged for two quarters.

The first-stage regression results (Appendix 2) indicates that government fleet rebate and fueling infrastructure grants increase E85 station density as expected, they are thus strong instruments in the IV models. However fueling station tax credit is inconclusive in its usefulness in promoting new E85 stations. Moreover government fleet tax exemption negatively affects station build-up, counter-intuitively. These first-stage regression results indicate right away that fueling station tax credit and government fleet tax exemption don't qualify as good instruments in the IV models. Therefore regression (8) excludes these two incentive variables and only includes government fleet purchase rebates and fueling station grants as instruments.

We also see from the first-stage regression results that more recent government fleet purchase incentives and station incentives have more influence over the expansion of fueling stations than more dated ones, the same observation we had for the incentives targeted at FFV consumers. This observation infers that the results of regression (6) – with the more recent incentives as instruments, are more robust than regression (7) – where the instruments have less impact, as model (6)'s instruments can account more fully for the effect of FFV demand on E85 stations, therefore model (6)'s estimate of coefficient is more indicative of the single-directional impact of E85 station on FFV demand than that of model (7). The results indeed confirm this logic, as when stronger instruments are used, the coefficient of E85 stations in regression (6) is 0.044 less than that in regression (7).

The instruments in regression (8) are government fleet purchase rebates lagged for two quarters and fueling station grants lagged for one quarter. After taking out the less effective incentive types in the instruments list, the coefficient on E85 stations is 0.028 less than that in regression (6).

The main result to take away from these regressions is that there is a significant and sizable effect of the number of E85 stations on flex fuel vehicles' demand. Moreover, this is robust to instrumenting for E85 stations, indicating that this is not simply a correlation resulting from fueling station owners decide to provide E85 where flex fuel vehicle demand is relatively high.

Across these types of models, the effect of E85 stations is greater for random-effects tobit models than for fixed-effects models, and for IV models than for random-effects tobit models. To compare the results of the three types of models, I take model (2), model (4), and model (8) for the reasons stated above. Fixed-effects model predicts a 0.075% increase in FFV share with one more station per million people while random-effects tobit model estimates a 0.098% increase, and IV model estimates a 0.12% increase. Tax credit is significant at the 10% level for the fixed-effects model, while it’s significant at the 1% level for the other two models, with the expected positive sign. Purchase rebate is significant at the 5% level for the fixed-effects model, and at 1% for the other two models, with the expected positive sign. Purchase loans is significant at the 5% level in fixed-effects model, at 10% level in the random-effects model with the expected positive sign, but not significant in the IV model. Tax exemption, on the other hand, is significant at 1%, 10%, and 1% for the three models but with the negative sign.

As I have discussed in 4.4.4, the number of MSAs that have variable tax exemption offer and purchase loan offer are a lot fewer than those that offer income tax credit and purchase rebates. This makes the positive and significant estimates of the coefficients for these latter two types of incentives to be more convincing and persuasive.

On the other hand, the effect of purchase loans turns out to be inconclusive, which means that we could not determine whether these loan offers have an impact based on the sample alone. The negative estimate on tax exemption means that based on the 5 MSAs in Massachusetts that offer this kind of incentive, the result suggests that this incentive produces counter-productive effects on the demand of FFVs in Massachusetts. Possible causes might be related to the variable's very limited number of MSAs which also includes cross state MSA as well as very limited number of states. As the estimate is significant at the 1% level, at most we can say is that the provision of tax exemption is counter-effective in Massachusetts, while this remark can't be made for the rest of the country.

Taking regression (8) as the preferred model, the estimate on E85 stations means that one more E85 fueling station per million people increases flex fuel vehicle's share in total new vehicles sold the next quarter by about 0.12%. The estimated effect of income tax credit provision on boosting FFV demand is about 2%. Having purchase rebates increases FFV demand by about 1.47%.

7 Conclusion

In order to achieve national goals of energy independence and environmental protection, ethanol is promoted as an alternative fuel in transportation because it can be domestically produced on a large scale and emits fewer pollutants than gasoline. E85 as a fuel can only be used in flex fuel vehicles which can run on either gasoline or E85. Although the number of FFVs sold has been increasing in the past few years, E85 consumption has yet to be increased to significantly displace oil imports and consumption. Without the widespread availability of E85, ethanol consumption is still limited. Only by making it more convenient for consumers to use FFVs through increasing the availability of the fuel could there be more consumers who are willing to buy and use FFVs.

The diffusion of systems like the flex fuel vehicle demand and E85 fueling stations could be marked by bottlenecks in which one side of the market is awaiting the other before making its own commitments (Gandal, Kende, and Rob, 2000). The aim of this paper is to provide an empirical counterpart to this literature, namely, to quantify the importance of complementarities for this particular system. Specifically, the more available the fuel E85 is, as represented by more E85 stations available, the more prevalent flex fuel vehicle purchases are going to be. This is useful for understanding the actual dynamics of the system, and to aid in the selection of strategies that might affect the dynamic. In this case it is important and effective to increase investment and support for building more E85 stations where they are scarce.

In addition to the importance of complementary E85 stations, state incentives for FFV consumers are also important in stimulating FFV diffusion. Previous research has asserted the effectiveness of tax incentives in stimulating hybrid vehicle demand (Gallaghper and Muehlegger, 2010). Similarly, I find that tax credit is effective for flex-fuel vehicle diffusion as well. Previous research has argued that federal tax credit for ethanol producers is cost ineffective in terms of reducing CO_2 emissions and gasoline consumption (Metcalf, 2007). However, the assumption is that ethanol demand comes almost entirely from usage in conventional gasoline or E10. As I demonstrated in this paper, the effect on flex fuel vehicle diffusion is significant when state tax credit incentives are applied to E85 consumers, in this case the cost effectiveness is significantly increased due to the larger proportion of ethanol used in E85 and the resulting significant decrease in gasoline consumption and CO_2 emission.

8 Limitations and Further Research

Ethanol cannot be blended with gasoline at the refinery and pumped through regular pipelines because it can corrode and crack the pipes and water can often seep into pipeline systems, damaging the fuel in ways that don't affect gasoline. Instead, it is transported on rails, barges, and trucks in relatively small batches to storage terminals. These means increase the cost and energy required in ethanol transportation.

As state incentives targeted at E85 stations only have very weak effect, they are weak instrument and couldn't account for possible endogeneity very well. In further research, a possible instrument to consider could be the closeness of each MSA to the nearest production facility or refinery (Corts used it as one of his independent variable), as the longer the distance is, the more expensive and less attractive the fuel is, and the less likely that there would be many stations choose to offer the fuel.

There are also other special events and developments that could impact the E85 stations landscape and therefore may qualify as instrument for the number of E85 stations. For example, the first ethanol pipeline went into operation in December 2008 which ran from Tampa to Orlando, Florida (KMP, 2008). This event could decrease the expected cost to transport ethanol along the pipeline regions and likely to increase the provision of the fuel along the way. I didn't incorporate this particular event into my instrument variable because it only applies to MSAs within one state, and the effect is therefore not likely to be very pronounced. However as a transnational ethanol pipeline becomes a reality, its impact on the number of E85 fueling stations will be a lot stronger.

APPENDIX

Appendix 1: Table of First-Stage Regression Results

	(1) E85 statio~e	(2) E85 statio~e
gas_e85	-0.507**	-0.518**
	[0.166]	[0.166]
govtReb2	1.322**	
	[0.505]	
govTax2	-2.307**	
	[0.819]	
stationGrant1	3.180***	
	[0.712]	
stationTax1	0.577	
	[0.501]	
log_travel	9.313	9.162
	[5.332]	[5.368]
Tax_Credit	-2.066***	-2.001**
	[0.620]	[0.621]
Rebate_Purchase	1.756***	1.742***
	[0.483]	[0.477]
Loan_Purchase	3.257**	3.328*
	[1.168]	[1.332]
Tax_Exemption	-2.883***	-2.915***
	[0.544]	[0.549]
govtReb3		1.238*
		[0.504]
govTax3		-2.028*
		[0.859]
stationGrant2		2.954***
		[0.664]
stationTax2		0.529
		[0.496]
Constant	-102.6*	-99.75*
	[47.62]	[47.83]
Observations	6383	6383
R-squared	0.314	0.310

Standard errors in brackets
* p<0.05, ** p<0.01, *** p<0.001

Appendix 2: Full Table of Results

	(1) ffv_share	(2) ffv_share	(3) ffv_share	(4) ffv_share	(5) ffv_share	(6) ffv_share	(7) ffv_share	(8) ffv_share
main								
E85_Stat~1	0.0476**	0.0750***		0.0984***		0.149***	0.193***	0.121**
	[0.0165]	[0.0214]		[0.00859]		[0.0411]	[0.0448]	[0.0419]
gas_e85	-1.210***	-1.263***	-1.075***	-1.246***	-1.057***	-1.212***	-1.181***	-1.231***
	[0.0930]	[0.0969]	[0.103]	[0.180]	[0.180]	[0.182]	[0.184]	[0.182]
Q1	-3.090***	-2.960***	-2.484***	-2.939***	-2.461***	-2.895***	-2.857***	-2.920***
	[0.0681]	[0.0778]	[0.0679]	[0.0935]	[0.0887]	[0.100]	[0.102]	[0.100]
Q2	-2.749***	-2.645***	-2.628***	-2.631***	-2.613***	-2.601***	-2.574***	-2.618***
	[0.0684]	[0.0738]	[0.0727]	[0.0829]	[0.0837]	[0.0867]	[0.0880]	[0.0866]
Q3	-1.750***	-1.658***	-1.647***	-1.651***	-1.639***	-1.636***	-1.623***	-1.645***
	[0.0469]	[0.0495]	[0.0492]	[0.0823]	[0.0830]	[0.0834]	[0.0843]	[0.0832]
Year_07	-13.18***	-12.95***	-12.27***	-12.91***	-12.26***	-12.53***	-12.28***	-12.69***
	[0.264]	[0.345]	[0.317]	[0.139]	[0.129]	[0.268]	[0.286]	[0.271]
Year_08	-13.26***	-13.14***	-13.16***	-12.98***	-13.01***	-12.83***	-12.64***	-12.95***
	[0.239]	[0.322]	[0.314]	[0.138]	[0.138]	[0.221]	[0.234]	[0.224]
Year_09	-10.80***	-10.86***	-10.86***	-10.82***	-10.83***	-10.64***	-10.51***	-10.73***
	[0.197]	[0.264]	[0.257]	[0.118]	[0.117]	[0.169]	[0.177]	[0.170]
Year_10	-6.221***	-6.533***	-6.562***	-6.572***	-6.612***	-6.404***	-6.327***	-6.453***
	[0.149]	[0.214]	[0.209]	[0.110]	[0.111]	[0.133]	[0.137]	[0.133]
Year_11	-3.040***	-2.998***	-3.000***	-2.978***	-2.980***	-2.938***	-2.903***	-2.961***
	[0.0871]	[0.0963]	[0.0960]	[0.101]	[0.102]	[0.106]	[0.108]	[0.106]
Tax_Credit	0.800	2.042*	2.011*	2.163***	2.124***	2.185***	2.270***	2.130***
	[0.671]	[0.865]	[0.876]	[0.251]	[0.248]	[0.268]	[0.272]	[0.268]
Rebate_P~e	1.605**	1.568**	1.064*	1.529***	1.057***	1.413***	1.321***	1.473***
	[0.559]	[0.531]	[0.481]	[0.227]	[0.224]	[0.249]	[0.253]	[0.249]
Loan_Pur~e	1.461*	1.140**	1.129**	1.326*	1.327*	0.962	0.855	1.030
	[0.620]	[0.343]	[0.385]	[0.548]	[0.544]	[0.563]	[0.569]	[0.562]
Tax_Exem~n	-1.951***	-1.586***	-1.442***	-0.707*	-0.629*	-1.334***	-1.184**	-1.431***
	[0.350]	[0.401]	[0.428]	[0.313]	[0.304]	[0.370]	[0.378]	[0.370]
log_income		1.915	2.616	-1.047	-0.396	1.392	1.079	1.593
		[1.824]	[1.815]	[0.859]	[0.846]	[1.015]	[1.030]	[1.013]
log_travel		4.255	4.303*	0.710	0.552	3.574***	3.167**	3.835***
		[2.204]	[2.138]	[0.874]	[0.869]	[1.034]	[1.054]	[1.034]
auto_p		21.64***	23.11***	26.80***	28.18***	21.51***	21.43***	21.56***
		[6.392]	[6.380]	[2.625]	[2.600]	[2.964]	[2.988]	[2.954]
college_p		-6.213	-5.578	-10.22***	-9.562***	-8.256*	-9.475**	-7.471*
		[5.412]	[5.447]	[2.498]	[2.472]	[3.322]	[3.382]	[3.320]
white_p		0.0529	-1.213	3.087*	2.429	0.963	1.505	0.613
		[4.007]	[3.747]	[1.381]	[1.347]	[1.982]	[2.009]	[1.979]
E85_Stat~4			0.0686***		0.0884***			
			[0.0203]		[0.00753]			
_cons	22.97***	-29.49	-38.28	8.916	0.977			
	[0.285]	[19.86]	[19.79]	[9.859]	[9.729]			
sigma_u								
_cons				3.629***	3.652***			
				[0.176]	[0.179]			
sigma_e								
_cons				2.321***	2.341***			
				[0.0216]	[0.0213]			
N	8418	6118	6384	6118	6384	6118	6118	6118

Standard errors in brackets
* p<0.05, ** p<0.01, *** p<0.001

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