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Building Out Alternative Fuel Retail Infrastructure: Government Fleet Spillovers in E85

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Building Out Alternative Fuel Retail Infrastructure:
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Abstract: One significant obstacle to meeting aggressive federal and state alternative fuel consumption targets is the relative scarcity of retail fueling stations that carry alternative fuels. Policies that encourage or mandate use of alternative fuel vehicles in government fleets, thereby increasing demand for such fuels, are one popular approach to stimulating further development of the alternative fuel retail infrastructure. I focus specifically on flex-fuel vehicles (FFVs) that burn E85, a combination of 85% ethanol and 15% gasoline, to study the impact of government fleet composition on retail alternative fuel infrastructure. Using data from six states in the Midwest that account for over 60% of US E85 stations, I show that government fleet adoption of FFVs leads to an increase in retail E85 stations. This finding persists when using instrumental variables techniques to address the endogeneity of government fleet FFV purchases. I also explore whether fuel station retail market structure has an effect on alternative fuel availability and find no evidence that the presence of stations affiliated with integrated gasoline producers has limited the availability of E85 at the market level. Finally, I examine how the effect of government FFVs on E85 availability varies by state and discuss the differing policy approaches that these states have taken.

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1. Introduction

Due to concerns about carbon emissions, air pollution, and "energy independence," the US federal government and a number of state governments have set ambitious targets for reducing gasoline consumption through increased consumption of alternative and renewable fuels. While this can include alternative fossil fuels such as propane and natural gas (which burn cleaner than gasoline and may be more abundant domestically), the policy emphasis has increasingly narrowed to renewable fuels—primarily ethanol and biodiesel—which have lower lifecycle carbon emissions and can be domestically produced. Biodiesel, produced largely from waste and virgin vegetable oils, is blended with traditional diesel (typically at a ratio of 20% biodiesel or less) and burned in standard diesel vehicles. Ethanol is sold in low-percentage blends with gasoline (typically 10% ethanol) that can be burned in regular gasoline vehicles. In either of these cases, increasing renewable fuel consumption is simply a matter of getting more alternative fuel blended into the fuel supply burned in traditional vehicles. However, increases in ethanol consumption increasingly come from a higher-percentage blend (85% ethanol), known as E85, which can be burned only in specially equipped vehicles known as flex-fuel vehicles (FFVs). Because large increases in consumption of E85 require both the widespread acquisition of FFVs and the build-out of a retail distribution infrastructure for E85, this market is characterized by indirect network effects similar to those present in hardware-software markets. As a result, the diffusion of this technology requires solving the chicken and egg problem created by such network effects. This paper examines some of the specific policies used to facilitate this diffusion in an effort to learn lessons that can ultimately be applied in other settings, as similar challenges will face other alternative fuel technologies such as hydrogen fuel cells and plug-in electrics.

In this paper I focus specifically on the use of government fleet acquisitions of FFVs as a stimulus to the development of the E85 retail distribution infrastructure. Many state and local government fleets buy FFVs, in part because of a federal mandate and a set of related programs implemented by state governments. Regulations requiring the acquisition of government fleet FFVs are intended to reduce conventional fuel consumption by government fleets directly, but also to reduce private consumption of conventional fuel by stimulating the availability of alternative fuels and alternative fuel vehicles for the public.[1] An array of tax credits and subsidies also provides other incentives for increased production, distribution, and retailing of E85. The combined effect of these policies, along with increases in gasoline prices, has been a rapid escalation of E85 availability and consumption in recent years.

I show in this paper that the acquisition of government FFVs does stimulate the establishment of E85 stations and that this result is robust to instrumenting to account for the endogeneity of government and individual vehicle purchasing behavior. In addition, this relationship is fairly robust across different states despite the fact that individual states have widely varying systems of tax credits and subsidies that affect the incentives to sell E85. Finally, contrary to suggestions by some industry observers, there is no evidence that the presence of gasoline stations affiliated with vertically integrated oil companies hinders availability of E85 in a market.

While alternative fuel consumption in general and the network effect aspect of their diffusion in particular are of interest to economists, little economics research on this subject exists. In a recent survey of economic policy issues related to automobiles, Parry, Walls, and Harrington (2007) discuss alternative fuels including E85 as one important response to the carbon emissions associated with gasoline consumption; they also specifically mention the difficulty of building an alternative fueling infrastructure as an impediment to increased consumption of alternative fuels. Di Pascoli, Femia, and Luzzati (2001) note that in their survey that a lack of access to a refueling network contributes to the lack of diffusion of alternative fuel vehicles. Kuby and Lim (2007) analyze the technical problem of designing the planner's optimal network of alternative fuel stations. However, there appears to be no research examining the economic incentives for fuel stations to provide alternative fuels or the effectiveness of policies adopted to spur the development of a retail infrastructure for alternative fuels.

[1] For example, the Department of Energy's final rule implementing the 1992 Energy Policy Act's fleet requirements states that: "To enable the Act's [conventional fuels] displacement goals to be met, alternative fuels must be readily accessible and motor vehicles that operate on these alternative fuels must be available for purchase. Thus, two important elements of reducing petroleum motor fuel consumption are: a nationwide alternative fuels infrastructure and the availability of alternative fueled vehicles for purchase at a reasonable cost by the general public in a wide variety of vehicle types and fueling options." (Department of Energy, 1996)

This paper takes a first step toward filling that gap in the literature. I draw on the methods employed in studies of other industries characterized by network effects. Many such studies appear in the recent industrial organization literature, including Gandal, Kende, and Rob's (2000) paper on CD players, Nair, Chintagunta, and Dube's (2004) paper on PDAs, and Clements and Ohashi's (2005) and Corts and Lederman's (2008) papers on the video game industry. While most of this literature estimates both sides of the network effect—that is, the effect of "software" availability on hardware demand and the effect of "hardware" installed base on software availability—in this paper I focus exclusively on the effect of the installed base of FFVs on E85 availability due to data constraints described later.

2. Industry Background

2.1 The rise of ethanol

The 2007 Energy Independence and Security Act, signed into law on December 19, 2007, established a renewable fuel standard (RFS) that requires fuel producers to use 9 billion gallons of US-grown biofuels in 2008 and 36 billion gallons of the same by 2022. While biofuels include for this purpose other fuels such as biodiesel, much of the increase mandated by this RFS is expected to come from ethanol. This represents a dramatic increase over 2007 US consumption of roughly 6 billion gallons of ethanol. Moreover, this 2007 level is roughly three times US consumption in 2002, so ethanol consumption had already been on a rapid increase prior to the establishment of this new goal.

Much of the increase in ethanol consumption comes through increased blending of ethanol in gasoline for use in conventionally fueled vehicles, all of which can burn blends up of to at least 10% ethanol. Ethanol is used in such low-level blends as one of the additives in premium gasoline, to meet explicit state regulations on ethanol content, and to meet federal clean-air requirements for reformulated gasoline (RFG) sold in urban areas. A small but increasing portion of ethanol consumption is accounted for by E85. However, this amount remains relatively small compared to overall ethanol consumption. For example, 2006 figures available for Wisconsin indicate that ethanol blended as E85 accounted for only 2 million gallons of a total of 130 million total gallons of ethanol blended with gasoline in all formulations.

2.2. Flex-fuel vehicles

While all gasoline vehicles can burn blends of up to 10% ethanol, only specially designed flex-fuel vehicles (FFVs) can burn ethanol in its higher concentrations such as E85. FFVs can burn any combination of gasoline and ethanol up to 85% ethanol, meaning that the two types of fuel can be mixed in any proportion in a single fuel tank. The vehicle's engine control system includes sensors that determine the level of ethanol in the fuel and adjust the engine's function accordingly. There is essentially no difference in the performance of the vehicle, and no additional maintenance is required. The one difference apparent to the driver is the lower per-gallon mileage when fueling with E85, which is a direct consequence of its lower energy content compared to gasoline. E85 contains between 70% and 75% of the energy per gallon of gasoline, which limits the range of the vehicle and of course also affects the way one interprets the price per gallon of fuel.

A number of manufacturers market FFVs in the US, and most have done so for a number of years. Models offered tend to be pickup trucks, large sedans, SUVs, and minivans. FFVs are usually simply alternative versions of standard models (though some models are produced only as FFVs), and the manufacturer's cost of modifying a vehicle to be an FFV is estimated to be only around $100. The Alternative Motor Fuels Act of 1988 created incentives for automobile manufacturers to produce FFVs in order to help them meet their corporate average fuel economy (CAFE) standards (US Department of Transportation, US Department of Energy, and US Environmental Protection Agency, 2002). An FFV's mileage for CAFE purposes is calculated as miles per gallon of *gasoline* (not E85 or ethanol) consumed, assuming that the vehicle is fueled with E85 half the time. However, this credit was capped at the manufacturer level so that a particular manufacturer can improve its overall fleet fuel economy for CAFE purposes by a maximum of 1.2 miles per gallon through FFV production.

2.3 E85 fueling infrastructure

E85 is sold at retail primarily through traditional gas stations. The number of stations offering E85 has increased dramatically in recent years, roughly tripling in two years from around 400 in 2005 to around 1200 in 2007. The attractiveness for prospective E85 station operators hinges on three variables: the fixed cost of converting or installing the required tanks and dispensers, the price-cost margins they expect to earn per gallon, and the volumes of E85 they expect to sell. The fixed cost of preparing the station to handle E85 depends on the station's existing equipment and space for new equipment, as well as on various grants, tax credits, and subsidies available to at least partially offset these fixed costs. The price-cost margin will be determined in part by the cost of obtaining E85 at wholesale, in part by what consumers will pay, and in part by per-gallon subsidies and tax credits that accrue to the retailer. Expected volumes will be determined by the number of FFVs within a station's served market and also by the fueling patterns of the drivers of those FFVs.

To carry E85, a gas station needs a dedicated underground storage tank for E85. E85 is typically, though not always, dispensed through a separate pump. In either case, the pump being used for ethanol requires some modifications in the materials used in the hoses, etc., in order to withstand the greater corrosive properties of ethanol. The Department of Energy estimates the cost of equipping a station to carry E85 at $50,000-$70,000 if the station must install a new underground tank, and at $5,000-$30,000 if the station can convert existing tank and must only retrofit or replace dispensers. The National Renewable Energy Laboratory of the DOE distributes a publication entitled "E85 Retail Business Case: When and Why to Sell E85," which lays out a cash flow analysis of an investment in E85 pump installation (Johnson and Melendez, 2007). This publication considers many scenarios and a number of variables. Roughly speaking, the conclusion is that installation of an E85 pump, even with the expense of a new tank, is profitable if (1) the station can maintain enough tanks and pumps to continue selling premium gasoline, (2) margins are no lower than for regular gasoline, and (3) the volume of E85 is about equal to an average station's premium gasoline volume.[2] Break-even volumes are of course somewhat lower

[2] As an alternative way of looking at the link between FFVs and E85 availability, a joint report of the DOT, DOE, and EPA (2002) indicates (without supporting calculations) that about 200 FFVs are required to make one E85 station economically viable. Some quick calculations in the conclusion of this paper indicate that this is not too different from what is implied by the careful analysis of the NREL report.

if expenses are lower due to the presence of a spare tank and pump. There exist a number of federal and state tax credits for E85 infrastructure projects. NREL's analysis described above accounted for the federal tax credit, which was put in place by the Energy Policy Act of 2002. It provides a tax credit equal to 30% of the cost of E85 conversion, up to a maximum of $30,000. In addition, five of the six states I study have their own infrastructure tax credit programs or other subsidies for E85 infrastructure investment, which are described in the Appendix.

Existing research suggests that consumer willingness to pay for E85 is tied closely to the price of gasoline, which is to be expected given that every vehicle that burns E85 also burns gasoline. What the required discount to gas is remains a debated topic. Given that E85 has 25% to 30% less energy content per gallon, a consumer seeking solely to minimize fuel expenses would have very elastic demand near an E85 price that reflected that inherent energy content discount (i.e., if E85 sold at a 25% to 30% discount to gasoline on a per-gallon basis). Anderson (2008) shows that the preferences for ethanol relative to gas are somewhat diffuse, but that the marginal consumer is willing to pay a small price premium for ethanol over and above the energy content-equivalent price. Assuming that current levels of retail E85 penetration yield some local market power in E85, the retailer's optimal price is essentially a given discount from the gasoline price that reflects both the lower energy content of ethanol and the premium consumers are willing to pay for it. Therefore, the margin the retailer achieves is largely determined by the wholesale price it pays. This will be in part determined by the transportation costs incurred in delivering the E85, so proximity to a refinery is likely to be one important determinant of the attractiveness of offering E85. Ethanol is trucked from refineries to be blended at gasoline terminals, unlike gasoline, which travels primarily from refinery to terminal by pipeline. As a result, proximity to a refinery is an important determinant of wholesale ethanol prices.

One might also think that contractual arrangements between stations and fuel suppliers, especially in stations branded by integrated oil companies, could affect the decision to carry E85. The 2007 Energy Act banned integrated oil companies from restricting installation of E85 pumps, the advertising of E85 availability, and the acquisition of E85 from independent providers as part of franchise agreements. The extent to which such interference occurred prior to the passage of this act is unknown, though the discussion surrounding the passage of the legislation suggests that it was a concern.

2.4 Mandates for government fleets

The primary federal mandate on government fleets' acquisition and use of alternative fuel vehicles is the 1992 Energy Policy Act (EPAct). EPAct requires a fraction of annual state government fleet vehicle acquisitions to be alternative fuel vehicles (AFVs), a broad category that includes FFVs and many other vehicles, specifically those that run on natural gas, propane, blends of ethanol or methanol of at least 85%, pure biodiesel (B100), hydrogen, or electricity. (Hybrid electric vehicles do not qualify as alternative fuel vehicles.) This fraction has ratcheted up over time; since 2001 EPAct has required 75% of a covered state fleet's acquisitions of light-duty vehicles to be AFVs. EPAct also applies to federal fleets, but since federal vehicles are not registered with state DMVs, I have no data on federal fleet vehicles, and I do not discuss them further in this discussion of government fleet mandates. EPAct's AFV acquisition requirements also apply to corporate fleets of certain alternative fuels providers. As with federal government fleets, I have no data on these private fleets and I therefore do not discuss these mandates further.

A state fleet is covered by EPAct if its non-excluded vehicles total at least 50 vehicles and at least 20 of these non-excluded vehicles operate in an MSA included in EPAct's coverage. (Excluded vehicles are emergency vehicles, law enforcement vehicles, off-road vehicles, vehicles parked at private residences while not is use, and vehicles acquired for testing purposes only.) If it satisfies this condition, then 75% of the entire fleet's acquisitions must be AFVs (again excluding certain vehicles such as emergency vehicles).[3] Note that EPAct does not contain any explicit provisions about how these alternative fuel vehicles are to be fueled. With respect to the federal fleet, there is an executive order that requires each federal agency to use alternative fuels to meet at least half the fuel requirements of its alternative fuel vehicles. However, no such similar federal regulation applies to state fleets.

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[3] The EPAct regulations are fairly complex. Among other provisions, they provide an ability to bank credits over time, to acquire them from other fleets, and to partially offset (up to half in a given year) the required AFV acquisition credits through use of biodiesel (every 450 gallons of biodiesel consumed offsets one required AFV acquisition). Beginning in 2008 (after my data), states can also apply for a waiver of the AFV acquisition requirements based on a documented reduction in gasoline consumption through any means.

Complementing EPAct, a number of state laws and regulations require or encourage government fleets both to acquire alternative fuel vehicles and to fuel them with alternative fuels. These are difficult to exhaustively characterize, but examples contained in the Appendix demonstrate the nature of these requirements. The bottom line is that every one of these states has some kind of law, regulation, or executive order that aims both to increase the presence of AFV and/or FFVs in state fleets and to increase the proportion of alternative fuel used in those vehicles.

3. Data

The data consist of a single cross-sectional snapshot of the 567 counties comprising 6 states in the Midwest: Illinois, Indiana, Iowa, Minnesota, Missouri, and Wisconsin. These 6 states accounted for over 60% of US E85 stations at the end of 2007.

3.1 FFV registrations

R.L. Polk & Co. provided counts of all light-duty vehicles currently registered with state DMVs in the third quarter of 2007, with subtotals for private and government vehicles by ZIP code. I summed these to the county level, which is the unit of analysis throughout this paper. Within each of these categories (total, private, and government), they also provided a count of FFV vehicles (determined from the registered vehicle's VIN). Private vehicles are those registered to individuals or to firms and organizations who do not register enough vehicles to be deemed a fleet (10 vehicles in most states). Government fleet vehicles include state and local government fleet registrations, where again the threshold for being deemed a fleet is 10 vehicles in most states. Federal government vehicles have plates issued by the General Accounting Office rather than state DMVs and are therefore not included in this dataset. The excluded subcategories (i.e., the difference between total vehicles and the sum of private and government vehicles) are primarily rental vehicles and dealer registrations. In the present analysis, I use two variables capturing the number of FFV registrations: *government FFVs* and *private FFVs*. As described in a later section, I also use as an instrument the variable *all government vehicles*, which is the total number of government vehicles in the county without regard to fuel type.

One might worry that this variable misses some government vehicles because some small government fleets may not be registered as fleets, but as individual registrations. Such vehicles would be omitted from the government fleet category. As long as this is not systematic, it is simply measurement error that will tend to bias the coefficient on the government vehicle variables toward zero. One might also worry that some government fleet vehicles may be registered to the county corresponding to the fleet headquarters rather than to the place of use. State fleet managers I talked to disagreed about the extent to which this was likely to occur, but in at least one case where the state fleet numbers are known (and the entire fleet is centrally managed, unlike in some other states), my government fleet count in the capital county was smaller than the known state fleet size, suggesting that not all state vehicles are associated with the headquarters county. Since the government fleet number derived from state DMV data includes local and county vehicles, it is impossible to precisely double check the Polk numbers with data from state fleet managers.[4]

3.2 E85 stations and refineries

The Alternative Fuel Data Center (AFDC) within the Department of Energy's office of Energy Efficiency and Renewable Energy (EERE) maintains a list of all E85 fueling stations in the country. This list includes publically accessible E85 stations and also a number of E85 stations operated by a fleet owner (typically a government) that are accessible only to that fleet's vehicles. I exclude these private-access E85 stations from the analysis.[5] This source provides a name and complete address, allowing each station to be matched to a county. I sum the number of stations in each county to construct the variable *E85 stations*. For reasons described later, I also construct a variable *E85 stations w/in 50 miles* that is the sum of all E85 stations in counties

[4] On average in my 6 states, the counties containing the state capital account for about 6% of the state population and about 19% of the government vehicles registered in the state. Given the concentration of government personnel in and around the state capital, this multiple of about 3 does not seem completely implausible, and certainly does not seem to suggest that entire state fleets are being registered to the capital county. One state is a significant outlier in this regard. Missouri's capital county accounts for 35% of government vehicles but only 1.3% of the population. This ratio of 27 does seem to suggest over-representation of government vehicle registrations in the capital county. The other 5 states' ratios all fall between 0.5 and 5. I estimate the effect of government FFVs separately for each state in Table 4; Missouri is in fact one of the two states without a significant effect of *government FFVs*.

[5] In the 567 counties in this analysis, 19 counties have a total of 26 such private-access E85 stations.

within 50 miles of the focal county (excluding the focal county). For this and all other distance measurements in the paper, I use county population-weighted centroids from the Bureau of the Census.

I also obtained a list of ethanol refineries, with complete addresses, from the Renewable Fuels Association. This allows me to associate refineries with counties. I constructed the variable *refinery distance* as the number of miles to the nearest county with an ethanol refinery. The distance is 0 if one's own county has a refinery.

3.3 Gasoline stations and automobile dealers

The US Census Bureau's County Business Patterns database provides a count of gas stations in each ZIP code in 2006. I aggregate this to the county level and construct the variable *station density*, which is the number of gas stations in each county divided by that county's population. This variable captures differences in the intensity of competition of the retail gasoline market across counties, which could affect E85 availability. Another indicator of the state of the gasoline market in a county is the gas price, which reflects both competition and the costs of gasoline. I obtained from www.gasbuddy.com average county retail gasoline prices in May 2009, denoted *gas price* throughout the paper.[6]

To identify more detail about the gasoline stations in a county, I also create a list of gas stations from the iBegin Business Directory. This directory lists only about a third as many stations (a little over 12 per county) as County Business Patterns indicates exist (about 31 per county); however, it gives a business name for each station. Using this, each station is coded as being affiliated with a vertically integrated oil company or not. If the station's reported name included the name of a firm that owns an oil refinery, the station is coded as affiliated with a vertically integrated firm. No direct observation of the form of the contractual or ownership relationship between the fueling station and the vertically integrated firm it is affiliated with is available. I

[6] These gas prices, current as of the revision date, were obtainable for free, unlike retail gas prices that match more closely the timing of my other data. Since the determinants of cross-sectional heterogeneity in gasoline prices are likely to be fairly slow-changing, and since E85 availability would only respond to fairly permanent differences in gas prices, I consider these sufficient for present purposes.

therefore refer to these stations as affiliated with a vertically integrated producer, indicating that the station itself may or may not be actually owned by the integrated upstream firm. The iBegin directory includes complete address listings, allowing each station to be matched with a county. From this directory I calculate the percentage of vertically integrated gasoline stations in each county (where both the numerator and the denominator are from the iBegin data). I then create indicator variables for each quintile of the distribution of this percentage. All analysis performed on variables derived from the iBegin data is carried out using these quintile indicators.

I also obtain a database of automobile dealers from Oddity Software. This database includes a complete address, allowing dealers to be matched to counties. The business names in this directory include the names of the brands represented at each dealer. I calculate for each county the number of dealer-brands represented by all the automobile dealers in this directory. For example, if a county had two dealers—ABC Toyota and XYZ Toyota Lexus—then that county would have three dealer-brands, one Lexus and two Toyotas. AFDC provides a list of makes and models of FFVs marketed in the US. I match the dealer-brands in the dealer data with the manufacturers of FFVs to determine the number of FFV dealer-brands in each county. To continue the example, since Toyota has offered FFVs in the US but Lexus has not, this same county would have two FFV dealer-brands. I sum the number of FFV dealer brands in each county to create the variable *FFV dealer-brands*, which is used an instrument as described in a later section.

3.4 Demographics

The Census Bureau provides demographic data at the county level, as well as latitude and longitude of county population-weighted centroids and county square mileage. In the analysis presented, I use *population* and *population density* (population divided by the county's area in square miles) as controls. I also gathered and/or constructed from this source additional demographic variables: percent male, percent black, percent college graduates among adults, percent graduate degree holders among adults, percent of households earning over $100,000, the percent of those who work away from home who commute by car, and a set of variables capturing the age profile of driving-age residents (percent of driving-age adults between 16-29, 30-44, and 45-59, with 60+ being the omitted category).

From the Bureau of Economic Analysis, I gather data on the economic environment of each county and construct two variables that potentially control for heterogeneity in county characteristics. *Ag employment share* is the share of total employment in each county accounted for by agricultural employees. *Growth* is the percent growth in total payroll from 1997 to 2007.

Using data from www.uselectionatlas.org, I also constructed a variable defined as the percentage point margin by which George Bush outpolled John Kerry in the 2004 US presidential election (which is positive in 461 of the 567 counties).

3.5 Summary Statistics

Table 1 below presents summary statistics. The first two columns present the mean and the standard deviation over the entire dataset of 567 counties. The following two pairs of columns present split-sample summary statistics, where the counties are split into those with and without any E85 stations.

The split sample comparisons are suggestive of the paper's results. For example, it is clear that counties with E85 stations have more government FFVs, more government vehicles, and more private FFVs, both in absolute terms and in per capita terms, and are closer to the nearest ethanol refinery.

INSERT TABLE 1 HERE

4. Empirical Model

4.1 The basic model

I seek to estimate the effect of government fleet FFV acquisitions on the expansion of the E85 fueling infrastructure. There are many potential entrants into the E85 retail market, since almost any traditional gasoline station can, for a relatively modest investment, install the equipment required to dispense E85. Assuming free entry into this market, an individual firm's decision whether to offer E85 depends on the fixed costs of entry, the costs of fuel, the demand for E85, and the decisions of other potential entrants. The equilibrium number of firms is in turn determined by the fixed costs of entry, the variable costs of the fuel, and the demand for E85. I estimate this relationship in reduced form:

$$E85\_stations_i = \beta_0 + X_i\,\beta_1 + \beta_2\,government\ FFVs_i + \beta_3\,private\ FFVs_i + \varepsilon_i,$$

where X_i is a vector of explanatory variables that control for market-level differences in subsidies, fixed costs, costs of fuel, and demand for E85, and ε_i is a mean zero error assumed to be uncorrelated with X_i and the two counts of FFV registrations. Note that the number of E85 stations cannot be less than zero; this is therefore a regression with a dependent variable that is left-censored at zero. I describe later the econometric approach I take in addressing this censoring.

Demand for E85 depends on the number of FFV vehicles in the market, and also potentially on who owns those vehicles. I include *private FFVs* and *government FFVs* since the presence of private and government FFVs may affect incentives to offer E85 differently due to differences in their tendency to fuel with E85 rather than gasoline.

The control variables X_i include state dummy variables in all specifications to control for differences in fixed costs of entry due to differences in state-level subsidies and regulations. This also controls for differences in the variable cost of fuel derived from differential state tax treatment of ethanol at the blender or retail level. Also included in X_i in all specifications is *refinery distance*, which affects the variable cost of fuel. All specifications reported in this paper include *population* and *population density* as elements of X_i to control for county heterogeneity. Throughout Table 2, which presents alternative econometric approaches, I include only these variables (in addition to state dummies) in X_i because other variables contributed little additional explanatory power or had imprecisely estimated coefficients, and because the inclusion of additional variables made estimation of some of the models (the spatial GMM model described later, in particular) much more difficult due to their high degree of correlation.

After establishing a preferred econometric approach, I do include additional variables, recognizing that the number of E85 stations may be affected by other factors such as differences in market size, the number of gas stations that might potentially carry E85, the geographic proximity of stations to each other, the intensity of vehicle use in a market, and so on. In various specifications I control for these other potential sources of county heterogeneity by using the variables described earlier that reflect the conditions of the local gasoline market (*station density* and *gas price*), local economic conditions (*ag employment share* and *growth*), and demographics (the age, race, income, political, and education variables described earlier, as well as higher order terms in *population* and *population density*).

4.2 Identification and instruments

The basic identification in this empirical exercise comes from county-level differences in the number of government FFVs that is not explained by state fixed effects or by differences in population and population density (or other observable characteristics of counties, when included). Of course, one concern is that the number of government FFVs is endogenously determined and responds to E85 availability. In that case *government FFVs* effectively contains ε_i in the equation above through its dependence on the number of E85 stations. This implies that the assumption that ε_i is uncorrelated with the regressors is violated. In particular, since one would expect the dependence of *government FFVs* on *E85 stations* to be positive, this endogeneity generally tends to induce a positive bias in the coefficient on *government FFVs*. A second concern is that there could be unobserved determinants of the number of E85 stations (factors that contribute to ε_i) that are correlated with the unobserved determinants of *government FFVs*. For example, suppose that some counties had experienced their economic growth much more recently than others so that there were effectively mature counties and booming counties. This could lead to some counties having both a *smaller* number of E85 stations (since, for example, the newer stations in the booming counties would be less likely to have a spare tank that makes E85 conversion much cheaper[7]) and a *larger* number of FFVs (if, for example, a higher proportion of the government fleet was bought in recent years when ethanol and alternative fuel mandates and policies were in place), which would generally tend to induce a negative bias in the coefficient of interest. In general, omitted variable bias could induce negative or positive bias.[8]

I address both the endogeneity concern and the omitted variable problem through the use of instrumental variables. Specifically, I instrument for *government FFVs* with *all government vehicles*. This is almost certainly exogenous to the number of E85 stations in a county in the sense that it is not a factor in station owners' decisions to offer E85. However, one may remain concerned that it is correlated with unobservable determinants of E85 availability. It is not clear what such variables might be; for those that can easily be hypothesized as candidates (for example, government presence may be related to education levels, which may affect E85 demand) I include additional control variables in an effort to mitigate the effect of unobservable factors.

Private FFVs may also be endogenous or correlated with unobserved determinants of the number of E85 stations. [9] I therefore use instrumental variables to deal with the potential endogeneity of *private FFVs* as well as *government FFVs*. What is required as an instrument for *private FFVs* is a variable that is uncorrelated with the unobserved determinants of the number of E85 stations but that does affect the acquisition of FFVs by individuals. I use the number of FFV dealer-brands to instrument for private FFV registrations, on the assumption that increased availability

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[7] Older stations often have three separate tanks for regular, mid-grade, and premium. Newer pumps tend to blend mid-grade at the pump from two tanks. Conversion of this third tank at older stations is often the most cost-effective way to introduce E85 to a station.

[8] When discussing potential biases in this paragraph and elsewhere, I describe the contribution of the problem being discussed to the bias induced in the coefficient *other things equal*. The actual bias induced in a particular model will depend on, among other factors, the other variables included in the model and correlations between explanatory variables.

[9] One could argue that endogeneity of private FFVs is not a serious concern because individuals may not have bought FFVs specifically for their ability to burn E85. Anecdotal evidence suggests that many individual FFV purchases are in essence accidental, and that many FFV owners do not even know that their vehicle is an FFV (for example, the Flex Fuel Vehicle Club of America, http://www.flexiblefuelvehicleclub.org/aboutus.asp, states that part of its mission is to "encourage consumers to find out if they own an FFV now"). In this view, FFVs are produced and sold by automobile manufacturers for the CAFE credit benefits and then sold to the public without any emphasis on the vehicle's FFV capabilities. Treating private FFVs as exogenous in the models estimated in the paper does not substantially change the results.

of brands offering FFV models increases FFV purchases but has no direct effect on E85 availability. Again, one may be concerned that *FFV dealer-brands* is correlated with unobservable characteristics of the county that are relevant to E85 availability (for example, rural cities may have lots of sellers of large American vehicles, which tend to be brands that offer FFVs, and also have many consumers who are especially interested in fueling with E85 because they identify with the farmers who grow the corn it's made of). To deal with factors that can be easily hypothesized to be determinants of E85 demand or availability, I include additional control variables to try to limit the set of unobservable factors driving E85 availability.

4.3 Censoring

Because the value of the dependent variable—the number of E85 stations in a county—cannot take values below zero, this is a regression with a censored dependent variable. This means that the observations of the dependent variable do not fully reflect negative realizations of ε_i when the dependent variable is at the censoring threshold (in this setting, when a county has no E85 stations). In effect, the implied errors have a positive mean when explanatory variables are such that the predicted value of dependent variable is low, violating the assumption the assumption that they are uncorrelated with the regressors. Failing to account for this generally leads to a bias in estimated coefficients toward zero.

This is the classic setting for the application of Tobit regression. This assumes normality of the error ε_i and then uses this assumption to correct for censoring. To deal with censoring, I therefore estimate among other specifications an instrumental variables Tobit model using Stata's implementation of Newey's (1987) two-step estimator.

This is also an example of a "count data" model, for which Poisson models are frequently employed. However, there are two problems with employing a Poisson model in this specific application. One problem is that the Poisson model does not handle high proportions of zero observations very well. My data include over 45% zero observations of the dependent variable, while the Poisson model implies that I should have only about 25% zero observations given that the mean of the dependent variable is 1.36.[10] There are various econometric strategies for dealing with this by using two-regime models (where some observations are never exposed to the Poisson risk and are necessarily zeros, with the remaining observations exposed to the Poisson risk), such as the zero-inflated Poisson. However, application of such models in IV settings appears to be undeveloped. The second problem is that the Poisson functional form implies that the marginal effect of an additional FFV is proportional to the number of E85 stations (the marginal effect is $\exp(\beta_i)*y_i$). That is, the marginal effect of an additional FFV in a county with four E85 stations is forced to be four times as large as the marginal effect of an additional FFV in a county with one E85 station. This seems inconsistent with the basic economic logic of the E85 stations' entry decision. Due to the combination of these two problems, I employ the IV Tobit model as my preferred specification, but I do present results from two Poisson models in Table 2, which explores alternative econometric approaches.

4.4 Correlated errors

There are several reasons to expect that the errors in this regression (county-level unobservables) are not independent across observations. There are certainly relevant policy variables that vary from state to state, but to the extent that these have equal effects across counties in the state, they are fully absorbed in the state dummies included in all specifications. Thus, the concern here is about other correlations in unobservables across counties that occur either within subregions of a state or across state lines. Unobservable determinants of E85 availability that affect areas not corresponding to states could include the presence of a multi-county chain of stations that has greater efficiencies in, knowledge of, or fondness for developing E85 stations. Similarly, the effect of a wholesale gasoline terminal whose management was especially focused on selling E85 would generally have common effects across several nearby counties.

Because these sources of correlation in unobservables are likely to be geographically localized, I want to allow for the spatial correlation of errors. Indeed, my preferred specification would be an instrumental variables Tobit model that allows for spatial correlation of errors. However, I have

[10] The predicted proportion of zero observations under Poisson is exp(-y*), where y* is the average number of occurrences per observation.

been unable to implement such a model because the standard approach to dealing with spatial error correlation is to use Conley's (1999) GMM estimator for spatially correlated errors (hereafter referred to as "spatial GMM"), an approach that is inconsistent with the distributional assumptions required for Tobit estimation. [11]

I address this potential spatial correlation of errors in two ways. First, I test for the spatial correlation of errors by calculating Moran's I statistic using Stata's "spatcorr" command. As described later, tests on this statistic fail to reject the null hypothesis that errors are spatially uncorrelated. Second, I estimate Conley's (1999) spatial GMM estimator in a linear model. This allows correlation of errors that declines linearly in the distance between observations, with the correlation becoming zero at a specified threshold. The results are not particularly sensitive to the threshold employed; in the results presented, I use a threshold of 300 miles. Since the Moran statistic suggests no spatial correlation and the coefficient estimates and standard errors are very similar between linear IV and Conley's spatial GMM, I estimate all models in subsequent tables under the assumption that errors are not spatially correlated.

5. Results

5.1 Basic results and alternative specifications

Table 2 presents the results from the basic model of E85 station presence in a number of specifications. The objective here is to explore alternative estimation methods using a parsimonious model. In all specifications, the dependent variable is the number of E85 stations and the level of observation is a county. The explanatory variables include only population and population density in addition to the two measures of FFV presence and refinery distance. More complete controls for county heterogeneity are incorporated in later tables, but population and population density capture a great deal of the variation across counties and are consistently significant across specifications. The first five specifications employ all 567 counties in the 6 states studied, while the last two drop counties with no E85 stations, as described later.

[11] The files for implementation of this *x_gmm* command are available at http://faculty.chicagogsb.edu/timothy.conley/research/gmmcode/statacode.html.

INSERT TABLE 2 HERE

Column (1) presents the simple OLS model that does not account for endogeneity of FFV presence, the censoring of the dependent variable, or the potential correlation of errors. The remaining columns all present models that account for the endogeneity of both *government FFVs* and *private FFVs* using the identification strategy described previously; *all government vehicles* and the quadratic polynomial of *FFV dealer brands* are used as instruments. Appendix B presents the first stage OLS regressions. These yield sensible results with *all government vehicles* having a positive and significant coefficient in a regression explaining *government FFVs* and *FFV dealer-brands* having a positive and significant coefficient in the regression explaining *private FFVs*. The F-test for the joint significance of the instruments in each first stage rejects that they are equal to zero at 1% in both cases.

Column (2) presents the results of a simple linear IV model. This accounts for endogeneity, but not for potential spatial correlation of the errors or for censoring of the dependent variable. Note that all variables are highly significant and that the main effect of instrumenting on the coefficients of interest is an increase in the magnitude of the effects of both measures of FFV stocks. The column (2) point estimates imply that about 110 government FFVs or about 770 private FFVs would yield an additional E85 station in a county. They also imply that a county loses one E85 station for approximately every 200 miles further it is from an ethanol refinery. I assess these magnitudes in more detail later.

Column (3) presents the results of Conley's spatial GMM model, which accounts for endogeneity and spatial correlation of the errors, but not censoring. Before proceeding to deal with censoring, consider these results. First, notice the similarity between the spatial GMM results and the linear IV results, both in the point estimates and in the standard errors. The stability of the estimates suggests that spatial correlation may not in fact be of much concern in this setting. To test this, I applied Moran's (1950) test for spatial correlation to the residuals from column (2). The test fails to reject the null of no spatial correlation with a p-value of 0.34 or greater in separate tests allowing spatial correlation up to 250 miles, 500 miles, and 750 miles.

As a result of these findings, I employ ordinary standard errors in all remaining regressions and do not attempt to control further for spatial correlation.

The remaining columns (4)-(7) control in various ways for the censoring of the dependent variable at 0. As described in section 3, I explore three ways of dealing with this: IV Tobit, IV Poisson, and omitting the zero-valued observations. Column (4) presents the results of the IV Tobit regression. Note that all coefficients remain significant. The coefficients for the two FFV measures are change only modestly relative to column (2), but the coefficient on *refinery distance* becomes twice as large in magnitude. This is consistent with large distances from a refinery being an important determinant of which counties have no E85 retail presence at all, but playing a weaker role in the number of stations among counties that are fairly close to refineries.

Column (5) presents the results of the IV Poisson regression. All coefficients except for that on *government FFVs* remain significant. The coefficients here are not marginal effects as in the other specifications and so cannot be compared directly. Evaluated at the mean of the data, the marginal effects of *government FFVs* and *private FFVs*, respectively, are 0.0006 and 0.0022. Given the problems that Poisson regression has in accounting for the large proportion of counties without E85 stations in the model, it is not clear what one can make of these results. Column (6) presents the IV Poisson model estimated on only the set of counties with at least one E85 station. Here, coefficient estimates on both FFV measures from the Poisson model are significant, but that on refinery distance is not. This is generally consistent with the finding from the Tobit model that refinery distance plays a larger role in determining whether a county has any E85 stations than in determining how many stations it has given that it has at least one. Here, it is clear that the marginal effects implied by the coefficient estimates from the Poisson model are quite similar to those of the other regressions. Specifically, at the mean of the data, column (6)'s estimates imply marginal effects of 0.0033 and 0.0013 for government and private FFVs, respectively. Alternatively, the implied marginal effects for government and private FFVs in the Poisson model are the same as those from column (4) if one evaluates the marginal effect for a county with 3.0 and 3.6 E85 stations, respectively. The unconditional mean number of E85 stations in this sample is 2.5.

For comparison, column (7) presents results from estimating the basic linear IV model of column (2) on the sample of counties with at least one E85 station. The key coefficients are essentially unchanged. The one interesting change is the lack of significance and smaller point estimate of refinery distance, which is again consistent with the suggestion that this plays a more important role in determining whether a county has any E85 stations than in determining how many E85 stations it has if it has any.

As described in section 3, I take the IV Tobit model as my preferred specification for the remaining empirical work. I take confidence in it from the similarity of the results to the results generated by alternative models that could also be applied to deal with potential spatial correlation or with the censoring of the data.

The main result to take away from these regressions is that there is a significant and sizable effect of government FFVs on the presence of E85 stations. Moreover, this is robust to instrumenting for government FFV presence, indicating that this is not simply a correlation resulting from government fleet managers locating their FFVs in counties with relatively high E85 availability. The estimate in column (4), for example, indicates that adding about 100 government FFVs increases the number of E85 stations by one. This validates the basic premise of the government fleet mandate programs—that forcing FFV technology into use through government fleet mandates increases the incentive for private gasoline station owners to make E85 available at their stations.

In contrast, private FFV purchases have a much smaller effect on E85 availability. The estimate in column (4) indicates that about 560 private FFVs are required to increase the number of E85 stations by one. This is consistent with the view that many individual drivers of FFVs are interested in fueling their vehicle primarily with gasoline (possibly unaware of the vehicle's capabilities) and do not therefore contribute to the demand for (and therefore equilibrium availability of) of E85 or with a view that private vehicles are driven less intensively than government vehicles.

5.2 Additional county characteristics

Having established a preferred specification, I now include a number of additional explanatory variables to better control for county heterogeneity and to help rule out potential alternative explanations. Table 3 presents these results, all of which are modeled on column (4) of Table 2, which is repeated as column (1) of Table 3 for comparison.

INSERT TABLE 3 HERE

Column (2) adds two controls for differences in retail gasoline markets across counties. One might expect that the intensity of competition, measured by *station density* or retail *gas price*, to affect margins on gasoline, which might affect both the equilibrium margin on E85 and the opportunity cost of diverting a pump from gasoline sales to E85 sales. However, neither of these variables is significant when included in this regression. Column (3) adds instead two controls for the economic environment of the county: *agricultural employment share* and *growth*. *Ag employment share* could affect the number of E85 stations through preferences for supporting local agriculture in these corn-growing regions, through effects on vehicle mix, or through many other channels. The coefficients on both of these variables are significant, though their inclusion has very little effect on the point estimates or the significance of the main variables of interest. Both are negative, with *ag employment share* estimated to reduce E85 stations by 1 for every additional four percentage points of *ag employment share* (for context, the unconditional mean is 16.7%). Much of the effect one might expect from *ag employment share* is presumably eliminated by the inclusion of *population density*, with which *ag employment share* has a correlation of -0.29. The estimated effect for *growth* is quite small, though significant; each additional 10 percentage points of growth over the prior 10 years (the unconditional mean is 38.9%) is estimated to reduce E85 stations by 0.14 stations.

Column (4) controls more flexibly for population and population density. Making this change lowers the magnitude of the point estimate for *government FFVs* and raises the point estimate for *private FFVs*. Point estimates from this specification imply about 170 government FFVs lead to an increase of one E85 station, while about 320 private FFVs are required. It remains true that government FFVs have a larger effect than private FFVs and that the estimate for government FFVs are broadly in line with estimates from other sources mentioned in section 2.

Column (5) controls more fully for demographic characteristics. Including these variables changes the point estimates very little from column (1). The only interesting significant coefficient is the marginally significant positive coefficient on Bush-Kerry margin, which suggests that, even controlling for all the other demographic characteristics, a wider winning margin for Bush over Kerry in the 2004 election is associated with a larger number of E85 stations. However, this effect is quite small; a swing from a 20 point margin for Kerry to a 20 margin for Bush corresponds to only an addition 0.6 E85 stations. Column (6) adds all of these additional control variables to the model. The coefficient estimates are quite similar to those in column (4). This "complete" model yields point estimates for marginal effects of 160 government FFVs or 370 private FFVs to increase E85 stations by one.

5.3 Additional specifications and robustness checks

The first two columns of Table 4 present estimates from specifications testing additional hypotheses about the determinants of E85 availability. The third and fourth columns of Table 4 present two robustness checks.

INSERT TABLE 4 HERE

Column (1) includes indicator variables for a county's presence in each quintile of the distribution of the penetration of gas stations affiliated with vertically integrated oil and gas firms. Recall that this is of interest because there is some speculation among policy-makers and industry participants that the presence of stations affiliated with vertically integrated firms may hinder distribution of E85 and other alternatives to these firms' petroleum-derived fuels. The estimates in column (1) demonstrate that there is no evidence for this effect at the county level; the coefficients on the quintile indicator variables are not significantly different from zero individually, and tests fail to reject pairwise equality of the coefficients for every pair.

Recall that these are county-level regressions explaining total E85 availability in a county, not E85 availability at a particular station. Thus, a finding that vertically integrated station presence does not hinder E85 availability at the county level is in no way inconsistent with speculation that vertically integrated oil firms hinder E85 availability at their own affiliated stations. In fact, only 20% (155/772) of the E85 stations in the data are affiliated with a vertically integrated firm while an estimated 55% of all stations in these six states are.[12] In effect, what the regressions suggest is that this lower availability of E85 at vertically integrated firms' affiliates is more than offset by more independent stations carrying E85 in areas with high concentrations of vertically integrated firm affiliates.

Column (2) explores the possibility that there might be network effects or local spillovers in the availability of E85. This could happen if, for example, E85 pump installations or conversions in one market led to entry or learning by contractors that lowered the capital cost of installation or conversion for nearby stations including those in neighboring counties. To test this, I include in column (2) a count of E85 stations in counties within 50 miles of the focal county. As described in section 3, this is treated as endogenous, with the sum of all government vehicles in those same counties being used as the instrument. Adding this variable causes little change in the main coefficients of interest. The coefficient is signficant and negative, with the point estimate implying that 17 additional stations in these neighboring counties would reduce E85 stations in the focal county by one station. This would be consistent with a competitive substitution effect, where neighboring counties' E85 stations siphoned off demand from local stations among local FFV drivers. Given the small magnitude of the estimated effect, I do not make much of this finding, but rather take confidence in the main estimates from their robustness to the inclusion of this variable.

Column (3) interacts the main variable of interest—*government FFVs*—with state dummies. The instruments are the same as before, but with *all govt vehicles* now interacted with the state

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[12] Recall that the business directory used to estimate the percent of stations that are affiliated with integrated firms contains many fewer gasoline stations than are present in the County Business Patterns (CBP) data from the Census. The 55% estimate presented here is obtained by applying the county-level percent VI-affiliate numbers from the business directory to the CBP totals to estimate the total number of VI-affiliated stations, and then dividing this number by the sum of the CBP totals. That is, the estimate is a weighted average of the percent VI-affiliate figures from the business directory listings, where the weights are the CBP station totals.

dummies. The interesting questions in column (3) are whether the results of the previous specifications are being driven by a single state or two and whether the states have significantly different patterns of responsiveness to government FFVs that might be related to differences in tax credits and state fleet mandates. The evidence from column (3) suggests that the results are not driven by outlier states, but rather that government FFVs generally have a robust and positive impact on E85 availability across a wide array of particular state environments. Four of the states have positive and significant coefficients, with coefficients ranging from about 0.01 to about 0.025 (compared to about 0.01 in Table 3 column (1) for example). The two states without significant coefficients—Iowa and Missouri—have point estimates very close to zero (with at least two zeros to the right of the decimal place in every case—that is, with absolute value an order of magnitude smaller than the smallest significant effect). Of these, recall that Missouri is the state in which the fleet registration data quality is most suspect and that measurement error associated with capital county overrepresentation would tend to bias this coefficient toward zero.

6. Conclusion

The logic of using government fleet FFV mandates to encourage private adoption of E85 and FFV technology relies on two premises. First, forcing the adoption of FFV technology by government fleets is presumed to increase the incentive for private gasoline stations to offer E85 by creating demand for the fuel. Second, this increased availability of E85 at retail is presumed to increase retail demand for FFVs by stimulating the provision of the key complement, E85 fuel. The validity of the first assumption is demonstrated by the main empirical results of this paper. Unfortunately, the data available to me are not ideal for shedding light on the validity of the second assumption. I know only the stock of FFV vehicles; as discussed earlier, most of these vehicles were purchased prior to the widespread availability of E85, and many of the owners of these vehicles may not even know of the vehicles' capabilities. Data on the flow of FFV purchases in more recent years is required to estimate a credible model of retail FFV demand. Work on the determinants of demand for alternative fuel vehicles remains an important topic for future research.

The results of this paper confirm the basic validity of the idea that creating a government-owned installed base of alternative fuel vehicles can spur the development of a retail alternative fuel distribution infrastructure. This of course does not speak directly to the cost-effectiveness of this policy or of its effectiveness relative to other methods of achieving this goal. It is possible, however, to interpret the results somewhat more finely (and speculatively) to get some suggestive evidence that might be used to address these questions.

First, one can assess the magnitude of the main effect, which would be an important factor in a more complete evaluation of this policy. The results from Table 3 suggest that an E85 station is added for every 100-170 government vehicles, depending on the specification. Consider the magnitude of this effect. If the average fleet vehicle were driven 12,000 miles per year at 20 miles per gallon, each vehicle would consume 600 gallons of fuel.[13] At this rate, 130-170 vehicles burning 100% E85 would be required to consume the 80,000 to 100,000 gallons of fuel that the National Renewable Energy Laboratory's business model estimates an E85 station requires to profitably invest in converting an existing storage tank to E85 (after accounting for federal but not state tax credits). Alternatively, a joint report of the DOT, DOE, and EPA (2002) indicates that about 200 FFVs are required to make one E85 station economically viable. The range of estimates in Table 3 is broadly in line with these estimates of the fleets required to spur E85 availability. Given that many government vehicles are likely to sometimes be fueled with regular gasoline rather than E85, these number seem quite sizable.

It is also interesting to consider the relative marginal and total effects of private FFVs. The estimates in Table 3 imply that the magnitude of the marginal effect of a private FFV is between 1/5 and 1/2 of the effect of a government FFV. The fact that this effect is always smaller is consistent with the idea that private drivers may be less likely to fuel with E85 than government employees driving fleet cars.[14] However, since there are on average ten times as many private

[13] The *Transportation Energy Data Book* (2008) from Oak Ridge Natural Laboratories states that the average miles driven by a US federal fleet sedan in 2007 was 12, 372.

[14] There are several reasons this may be likely. One is that certain government mandates require fueling fleet FFVs with E85. Another is that, as mentioned in section 3, many private FFV owners may not even be aware that their car is an FFV or may have bought their vehicle without regard to its FFV capabilities. While one might expect government FFVs to have a smaller effect on public E85 availability if they are centrally fueled, there are in fact very few dedicated government fleet fueling facilities for E85; only 26 in the six states I study.

FFVs as government FFVs in a county, the total contribution of private FFVs to E85 demand and thus availability may well exceed the total contribution of government FFVs in some counties.

Second, consider the cost effectiveness of this government fleet strategy. Given that FFVs, when offered for a model, are typically available at the same price as gasoline-only vehicles, a fleet mandate that results in no distortions in fleet composition (i.e., a policy that does not, for example, lead fleet managers to buy larger vehicles than required in order to obtain FFVs) is essentially costless to implement. If, in addition, the fleet then fuels with E85 only when it is economical (taking into account the relative prices of fuels adjusted for the lower mileage of E85), a government fleet mandate is essentially a costless initiative that apparently yields sizable benefits in terms of stimulating E85 availability. Many of the state fleet acquisition mandates described in the Appendix (but not the federal EPAct mandate) include specific language aimed at preventing distortions of fleet composition. Likewise, many of the state fleet fueling mandates specifically require the purchase of alternative fuel only when it is cost-effective. It is important to note that the ability to pursue this strategy at such a low potential cost is a direct consequence of the complete "backward-compatibility" of FFVs—that is, the fact that they can also burn gasoline as efficiently as an ordinary car. A fleet mandate strategy would be inherently much more costly in a technology that had more limited compatibility with an existing standard fuel.

It is interesting to consider the backward-compatibility of the most common or promising alternative fuels besides ethanol. These include biodiesel, electricity from the grid, and hydrogen, which can either be used to generate electricity on board in a fuel cell or be burned in a combustion engine. Biodiesel (very similar to petroleum diesel, but created from virgin or waste oils and fats) can be burned in standard diesel engines in up to 20% blends with petroleum diesel (the common 20% blend is denoted B20). Thus, there is really no chicken-and-egg problem for such blends; a large installed base of vehicles capable of burning these blends exists already. More interesting is the case of pure biodiesel (B100), which does require a specially modified vehicle. Such vehicles can also burn lower blends or biodiesel or pure petroleum diesel. They are thus fully backward compatible with an existing standard fuel, much like FFVs. If the goal were to stimulate a retail infrastructure for B100, then the E85/FFV experience suggests that a government fleet mandate for B100-compatible vehicles could be effective.

When used in combustion engines, hydrogen is often (though not always) burned in up to 50% blends with compressed natural gas (CNG). Vehicles that are capable of burning such blends are typically capable of burning pure CNG as well. Thus, some hydrogen combustion engines are backward compatible with a somewhat more accessible fuel (according to the Alternative Fuels Data Center at the Department of Energy, there were 778 CNG stations nationwide at the end of 2008, but only 46 hydrogen stations).[15] However, over half of existing CNG fueling stations are limited to private access (that is, used only for fueling specific government or corporate fleets), so a push for fleet adoption of hydrogen-blend combustion vehicles would likely be much less effective in stimulating provision of fueling sites available to the public. Cars that run on hydrogen fuel cells offer even less backward compatibility and are therefore also less well-suited to a fleet push strategy.

Plug-in electric vehicles that take their electricity from the grid present a different set of issues. Standard plug-in electric vehicles are not compatible with any other fuel. However, because all plug-in vehicles, including those that are privately owned, are likely to be charged at a private charging station (that is, at home, at night), the need for a public infrastructure is more limited. Both fleet vehicles and private vehicles share a need for charging stations—not for everyday use, but for extended range, such as on the highway. Thus, the fueling infrastructure needs of private and fleet vehicles overlap well, and it seems likely that government fleets of plug-in electrics would stimulate provision of public charging stations to some extent, though this would be highly sensitive to the nature of the use of the fleet vehicles (specifically, whether they were used for distances sufficient to require daytime charging). In contrast, plug-in *hybrid* electric vehicles are backward-compatible in the sense that they can also be fueled with gasoline; however, it seems likely that a government fleet plug-in hybrid would take its alternative fuel (electrical charge) at night from a private charging station and would more likely take on its non-alternative fuel (gasoline) from the publicly accessible infrastructure. Thus, a government fleet of such vehicles would likely do little to stimulate the provision of public charging stations.

[15] See www.afdc.energy.gov/afdc/fuels/stations_counts.html.

Finally, one can attempt to assess what other policies such as tax credits and subsidies complement the strategy of mandating government fleet FFV acquisition. A gasoline station's net profit from installing an E85 pump, ignoring any cannibalization of existing gasoline sales, is given by the quantity sold times the profit margin, less the fixed cost of conversion/installation (Q*(P-AVC)-F). Fleet mandates work to improve this payoff by increasing the volume *Q* of E85 sold. Infrastructure tax credits effectively lower the fixed cost *F*, while per-gallon retailer tax credits lower the average variable cost and raise the effective profit margin on each gallon sold. While such a tax credit may in principle be passed on in lower retail prices if the retail market is competitive or absorbed by the supplier if the wholesale market is monopolized, in general the E85 retailer will capture some portion of this as a higher retail margin.

Without taking a stand on the overall effectiveness of various subsidies and incentives one can infer that certain policies are likely to be complementary to government fleet mandates. These are policies that raise the marginal impact of a government FFV on expected volumes or raise the marginal impact of expected volumes on profits. An example of the latter is any tax credit that is calculated per gallon and that accrues to the retailer. Iowa and Indiana have per gallon tax credits to the retailer, while every one of these six states except Wisconsin has a lower fuel tax for E85, which theoretically has a similar effect to a per gallon E85 retailer tax credit. Note that an infrastructure tax credit—in place at the federal level and separately in every one of these states except Missouri—has no effect on the marginal impact of expected volumes. An example of a policy that raises the marginal impact of a government FFV on expected volumes is a government fleet alternative fueling mandate, which should raise the gallons of alternative fuel consumed by each alternative fuel vehicle in the fleet. Such mandates are in effect in some form in all six of these states. Another example of a policy that could influence expected volumes, as the firms perceive them (which is the relevant measure), is a policy of circulating information on the location of the government fleet alternative fuel vehicles. In fact, state fleet and renewable energy officials from at least two states have confirmed to me that they engage in this kind of information dissemination. It is not possible to assess the relative importance of these complementary policies empirically since such policies vary only at the state level, leaving essentially six observations for inference, with comparisons between states conflating many sources of heterogeneity

More work remains to improve our understanding of policies for encouraging the dissemination of alternative fuel vehicles and their accompanying fueling infrastructure. Further work examining the fledgling infrastructures associated with biodiesel, hydrogen, and plug-in electric vehicles and their fueling infrastructure would be useful. Each technology has different fuel compatibility features, which affects the ease or difficulty of pursuing an E85-like "hardware first" strategy, which will in turn affect the feasibility of a government fleet-based push for dissemination.

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Table 1: Summary Statistics

	All counties (N=567)		Counties without (N=258)		Counties with E85 (N=309)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
E85 stations	1.36	2.16	0.00	0.00	2.50	2.39
government FFVs	14.30	88.76	1.49	4.44	25.00	119.20
private FFVs	1405.82	3488.81	582.10	591.46	2093.58	4586.16
all government vehicles	135.02	829.40	24.26	49.96	227.50	1114.99
FFV dealer-brands	2.93	4.77	1.53	1.81	4.09	6.01
refinery distance (miles)	51.34	45.37	61.96	49.46	42.47	39.60
proportion gas stations affiliated with VI firm	0.47	0.28	0.42	0.29	0.50	0.26
E85 stations within 50 miles	15.90	16.35	10.09	7.32	20.74	19.87
population (100,000s)	0.66	2.50	0.25	0.33	1.00	3.33
population density (100s per sq mile)	1.34	4.49	0.73	3.45	1.85	5.15
station density (stations per 100,000 population)	73.58	27.96	79.68	28.95	68.48	26.08
gas price ($ per gallon)	2.46	0.12	2.44	0.13	2.48	0.11
agriculture employment share	0.17	0.13	0.21	0.13	0.14	0.11
total payroll growth 1997-2007	0.39	0.16	0.38	0.16	0.40	0.15
% male	49.45	1.38	49.47	1.54	49.43	1.23
% college degree	15.66	6.50	13.45	4.61	17.50	7.23
% graduate degree	4.99	2.66	4.31	1.97	5.55	3.00
% earn over $100,000	6.18	3.73	4.90	2.21	7.26	4.36
% black	2.20	4.92	1.74	5.19	2.58	4.65
Bush-Kerry '04 margin	0.16	0.18	0.18	0.18	0.14	0.18
% age 16-29	0.22	0.05	0.22	0.04	0.23	0.05
% age 30-44	0.28	0.03	0.27	0.03	0.28	0.03
% age 45-59	0.24	0.02	0.24	0.02	0.24	0.02
% commute by car	0.95	0.03	0.95	0.02	0.95	0.03
per 10,000 population						
government FFVs	1.02	4.58	0.44	0.93	1.49	6.11
private FFVs	13.73	19.78	8.60	9.80	18.01	24.46
all government vehicles	251.36	44.69	245.87	41.62	255.95	46.67

Note: All differences in means between the two subsamples are statistically significant at 5% except growth and % male.

Table 2: Basic Results

	dependent variable: *E85 stations*						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	Linear IV	Spatial GMM	IV Tobit	Poisson IV	Poisson IV	Linear IV
government FFVs	0.0053**	0.0095**	0.0093**	0.0100**	0.0005	0.0013*	0.0090**
	(0.0010)	(0.0012)	(0.0016)	(0.0018)	(0.0009)	(0.0006)	(0..0014)
private FFVs	0.0009**	0.0013**	0.0014**	0.0018**	0.0017**	0.0005**	0.0012**
	(0.0001)	(0.0001)	(0.0003)	(0.0002)	(0.0003)	(0.0001)	(0.0001)
refinery distance	-0.0058**	-0.0051**	-0.0057**	-0.0106**	-0.0042**	-0.0007	-0.0021
	(0.0014)	(0.0015)	(0.0019)	(0.0025)	(0.0016)	(0.0009)	(0.0026)
population	-0.0094**	-0.0147**	-0.0156**	-2.1270**	-0.0190**	-0.0062**	-1.2732**
	(0.0009)	(0.0014)	(0.0037)	(0.2193)	(0.0033)	(0.0010)	(0.1721)
population density	-0.0325	-0.0656**	-0.0885+	-0.1126*	-0.0602*	-0.0239	-0.1850**
	(0.0209)	(0.0222)	(0.0529)	(0.0465)	(0.0307)	(0.0218)	(0.0459)
Observations	567	567	567	567	567	309	309
	full sample	full sample	full sample	full sample	full sample	E85 stations>0	E85 stations>0

All specifications include (coefficients not shown) state dummies.
Excluded instruments in columns (2)-(7) are *all government vehicles* and the quadratic polynomial of *FFV dealers*.
Standard errors in parentheses: ** significant at 1%; * significant at 5%; + significant at 10%.

Table 3

	IV Tobit: dependent variable = *E85 stations*					
	(1)	(2)	(3)	(4)	(5)	(6)
government FFVs	0.0100**	0.0100**	0.0096**	0.0058**	0.0102**	0.0062**
	(0.0018)	(0.0018)	(0.0018)	(0.0018)	(0.0019)	(0.0020)
private FFVs	0.0018**	0.0018**	0.0017**	0.0031**	0.0021**	0.0027**
	(0.0002)	(0.0002)	(0.0002)	(0.0005)	(0.0003)	(0.0008)
refinery distance	-0.0106**	-0.0105**	-0.0111**	-0.0106**	-0.0112**	-0.0109**
	(0.0025)	(0.0025)	(0.0025)	(0.0025)	(0.0026)	(0.0025)
population	-2.1270**	-2.1408**	-1.9157**	-4.5755**	-2.5070**	-3.7262*
	(0.2193)	(0.2470)	(0.2595)	(1.1917)	(0.3955)	(1.8123)
population density	-0.1126*	-0.1082*	-0.1109*	-0.6161**	-0.0939*	-0.5115*
	(0.0465)	(0.0459)	(0.0439)	(0.1930)	(0.0440)	(0.2501)
station density		0.0016				-0.0001
		(0.0049)				(0.0052)
retail gas price		-0.7873				1.6682
		(2.1623)				(2.0846)
ag employment share			-2.4254*			-3.7964**
			(1.1123)			(1.2356)
growth			-1.3530*			-0.8487
			(0.6786)			(0.6944)
population^2				0.0133		0.0093
				(0.0109)		(0.0160)
population density^2				0.0149**		0.0115**
				(0.0035)		(0.0038)
% male					-0.0862	-0.0484
					(0.0823)	(0.0818)
% college degree					-0.0456	-0.0062
					(0.0675)	(0.0633)
% graduate degree					0.0332	0.0356
					(0.1428)	(0.1468)
% earn over $100,000					-0.1263	-0.0596
					(0.0787)	(0.0977)
% black					0.0366	0.0311
					(0.0289)	(0.0279)
Bush-Kerry '04 margin					1.5099+	0.9232
					(0.775)	(0.7252)
% age 16-29					8.1658*	2.3599
					(4.1022)	(4.3997)
% age 30-44					-4.5327	-10.0996+
					(5.8193)	(5.8752)
% age 45-59					-2.4903	-15.6507+
					(8.9747)	(8.9496)
% commute by car					-1.8421	3.0146
					(6.4983)	(6.3234)
Observations	567	567	567	567	567	567

All specifications include (coefficients not shown) state dummies.
Excluded instruments in all columns are *all government vehicles* and the quadratic polynomial of *FFV dealers*.
Standard errors in parentheses: ** significant at 1%; * significant at 5%; + significant at 10%.

Table 4

	IV Tobit: dependent variable = *E85 stations*		
	(1)	(2)	(3)
government FFVs	0.0096**	0.0118**	
	(0.0018)	(0.0020)	
private FFVs	0.0018**	0.0021**	0.0022**
	(0.0002)	(0.0002)	(0.0002)
refinery distance	-0.0104**	-0.0163**	-0.0101**
	(0.0025)	(0.0031)	(0.0025)
population	-0.0207**	-0.0250**	-0.0298**
	(0.0022)	(0.0029)	(0.0038)
population density	-0.1056*	-0.0776+	-0.1118
	(0.0458)	(0.0462)	(0.0786)
2nd quintile VI presence	0.2304		
	(0.3188)		
3rd quintile VI presence	0.0537		
	(0.3357)		
4th quintile VI presence	-0.1834		
	(0.3506)		
5th quintile VI presence	-0.0352		
	(0.3417)		
E85 stations w/in 50 miles		-0.0577**	
		(0.0166)	
*government FFVs * IA*			-0.0026
			(0.0045)
*government FFVs * IN*			0.0104+
			(0.0059)
*government FFVs * IL*			0.0257**
			(0.0054)
*government FFVs * MN*			0.0085**
			(0.0026)
*government FFVs * MO*			0.0026
			(0.0030)
*government FFVs * WI*			0.0233*
			(0.0112)
Observations	549	567	567

All specifications include (coefficients not shown) state dummies.

Excluded instruments in all columns are *all government vehicles* (in column (3) this is interacted with state dummies) and the quadratic polynomial of *FFV dealers*. In column (2) the number of government vehicles within 50 miles is also used as an excluded instrument.

Standard errors in parentheses: ** significant at 1%; * significant at 5%; + significant at 10%.

Appendix A: Overview of state laws relating to E85[16]

Infrastructure subsidies

In Minnesota, a public-private partnership administered through the American Lung Association of Minnesota makes grants for up to the full value of the installation or conversion from a pool of funds derived largely from government grants. Four other states have infrastructure tax credits similar to the federal tax credit. Of these, Iowa's is the most generous, with a credit of 50% of cost on new stations and 75% of cost on conversions, both capped at $30,000. Illinois, Indiana, and Wisconsin have roughly similar programs, but with payments on conversions capped at the much lower level of $3,000-$5,000. Missouri does not to my knowledge have infrastructure tax credits.

AFV acquisition regulations

Missouri's new law is perhaps the strongest among the 6 states I study. Missouri requires 70% of its new fleet acquisitions to be specifically FFVs, not AFVs in general (Missouri Revised Statutes 414.400). Iowa fleets must purchase an AFV or hybrid electric vehicle (HEV) rather than a conventionally fueled vehicle if the desired model is available as an AFV or HEV (Executive Order 41, 2005). Minnesota law requires state fleets to acquire AFVs whenever they are available at similar cost to other vehicles and capable of serving the intended purpose (Minnesota Statutes 16C.135). In Illinois, state agencies are encouraged by executive order to set priorities for FFV acquisition, and in fact this has been interpreted rather strictly according to a fleet management official there (Executive Order 7, 2004). Wisconsin law requires acquisition of AFVs or HEVs whenever feasible (Wisconsin Statutes 16.045). Indiana requires agencies to buy biofuel vehicles whenever available and economically feasible (Indiana Code 5-22-5-9).

AFV fueling regulations

With respect to alternative fuels use, similar laws and regulations exist at the state level. In Missouri, 30% of the state fleet's fuel use must be alternative fuels (Missouri Revised Statutes 414.410). In Iowa, 60% of the fuel used in the state's FFVs must be E85 by 2009 (Executive Order 2, 2007) In Minnesota, the state fleet's FFVs must use E85 when it is reasonably available (Executive Order 3, 2006). In Illinois, an executive order requires fleet managers to encourage E85 use in FFVs and work to increase the availability of E85 for use in the fleet (Executive Order 7, 2004). In Wisconsin, an executive order requires the fleet to reduce petroleum use to specific targets over five year intervals, and the state has an Office of Energy Independence that tracks petroleum use and works to encourage biofuels use in the state fleet (Executive Order 141, 2006). Indiana requires agencies to buy biofuel whenever available and economically feasible (Indiana Code 5-22-5-9) and makes incentive transfer payments to local governments who use E85 in their FFV fleets (Indiana Code 8-14-2-8).

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[16] This summary is based on the AFDC's comprehensive "Laws and Incentives" state pages at http://www.eere.energy.gov/afdc/fuels/ethanol_laws.html.

Appendix B: First Stage Results

	First Stage OLS	
	(1)	(2)
	dependent variable:	
	ffv_govt	ffv_retail
refinery distance	-0.0051	-0.6336
	(0.0294)	(0.6498)
population	-66.60**	1504.72**
	(2.43)	(53.74)
population density	7.551**	-34.37**
	(0.4594)	(10.15)
all government vehicles	0.2243**	-0.4295**
	(0.0055)	(0.1206)
FFV dealer-brands	6.5607**	243.28**
	(0.5529)	(12.22)
(FFV dealer-brands)^2	0.0300	-5.1055**
	(0.0270)	(0.5958)
Observations	567	567
R^2	0.9015	0.9688
All specifications include state dummies.		
Standard errors in parentheses: ** significant at 1%.		