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Private Sector Engagement in the Self-Governance of Urban Sustainable Infrastructure: A Study on Alternative Fueling Infrastructure in the United States

Heewon Lee

Askew School of Public Administration and Policy, Florida State University, 600 W College Ave, Tallahassee, FL 32306, USA; hl17c@my.fsu.edu

Abstract: Greenhouse gas emission reduction and decarbonization goals drive citizens' interests in alternative fuel vehicles and have created fast-growing demands on alternative fuels. While governments are promoting the transition to alternative fuel vehicles, the lack of refueling and recharging infrastructure for the vehicles is a key barrier to the adoption. At the same time, the public sector cannot solely provide needed alternative fueling infrastructure due to limited financial resources. Consequently, governments in the U.S. have been working on facilitating the private sector's investment in alternative fueling infrastructure. The most common approach was financial incentive programs and policies, but the U.S. also promotes self-organized collaborative governance of alternative fuels across sectors at the local level. This paper asks whether these two approaches stimulate the private sector's engagement in providing alternative fueling infrastructure. This study uses the case of the Clean Cities program that targets the reduction in petroleum usage, adoption of alternative fuels and creation of self-governance at the local level. Local private businesses, local government agencies and non-profit organizations voluntarily participate in the local transition to alternative fuels. Therefore, this governance aims at facilitating more sustainable actions and business choices in the private sector. This paper tests the hypotheses of whether the local self-governance of Clean Cities increases privately-owned alternative fueling infrastructure using panel fixed-effects Poisson regression models. Based on the data of counties in 12 states from 2004 to 2015, the results of empirical analysis suggest that both self-governance and financial incentive programs are effective in increasing the engagement of private actors in providing alternative fueling infrastructure.

Keywords: alternative fuel governance; private sector engagement; sustainable urban infrastructure; alternative fueling stations

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1. Introduction

Urbanization and climate changes have posed challenges to policymakers across the globe, and governments have taken initiatives to pursue decarbonization. Global emissions have soared in the last three decades, which has led countries to pursue deep decarbonization since 2013 and build sustainable energy systems [1]. Following the trend, urban planning has focused on embedding the goals of sustainability, which are economic development, environmental protection and quality of life across policy domains [2]. One of the methods for achieving the climate and air quality goals is to adopt sustainable urban mobility strategies that aim for systemic decarbonization in the transport sector and providing sustainable transportation infrastructure. The transportation sector has been one of the largest sources of air pollutants, including carbon dioxide, carbon monoxide, nitrogen oxide, particulate matter and hydrocarbon. Transportation takes up the largest proportion (29%) of total greenhouse gas emissions in the U.S., followed by electricity and industry. As much as passenger cars have the largest emission in the transportation sector (762.3 teragrams CO_2, 40.6%), small, medium and heavy freight trucks had similar amounts of emission (767.5 teragrams CO_2, 40.8%) in 2019 [3].

For this reason, governments across the globe have formulated initiatives to set fuel economy standards and to promote alternative fuel vehicles (AFVs) and refueling infrastructure. The U.S. government has also defined alternative fuel as any fuel other than gasoline for transportation use, including biodiesel, E85, electricity, hydrogen, compressed natural gas (CNG), liquified natural gas (LNG) and liquified propane gas (LPG) [4]. For example, a network of Eurocities, which connects more than 200 cities in 38 countries in Europe, has pursued clean mobility to meet the goal of achieving a 90% reduction in emissions in the transportation sector by 2050, phasing out diesel and gasoline-powered vehicles which are the main reason for air pollution. The diesel and gasoline-powered vehicles would then be replaced with zero-emission and clean-fuel vehicles [5]. Especially, the U.S. Department of Transportation (DOT) has focused on the connectivity of AFVs so that vehicles can refuel and recharge along the national highway system [6]. To guarantee connectivity, strategic deployment of alternative fueling infrastructure and the construction of an integrated transportation system have been important tasks [7–9]. To meet the demands of AFV consumers and attain the decarbonization goal, the U.S. federal, state and local governments have invested resources to construct an infrastructure consisting of recharging and refueling stations [10]. However, local governments often face challenges to solely provide the infrastructure due to fiscal resource limitations [11,12]. To overcome this obstacle, the private sector can invest capital to deploy refueling and recharging sites for which the government has offered appropriate incentives and partnership programs [13]. While the number of privately owned alternative fueling stations is increasing, only a few studies have focused on whether these incentives and programs are an effective way to engage the private sector in supplying such infrastructure [14–16]. With the urbanization trend, many cities and counties are indeed experiencing faster carbonization because of heavier traffic from 1990 to 2019 in the U.S. [17]. Still, the urban environment provides fertile ground for implementing sustainable transport systems based on the large potential AFV user market [18–20]. Therefore, this paper attempts to assess how the different policies and programs induce the private sector to engage in supplying sustainable infrastructure and contributing to the attainment of sustainability goals.

This paper attempts to fill the gap in the alternative fuel infrastructure literature by providing an understanding of the multiple approaches taken to create urban sustainable infrastructure. In Section 2, this paper reviews how the private sector has been participating in the development of urban infrastructure. Section 3 briefly explains the Clean Cities program which is the context of the study and shows how the case is adequate to study the proposed research question. This is followed by Section 4, which discusses the theoretical background of self-governance and private sector engagement in supplying sustainable infrastructure and suggests hypotheses to be tested. After laying out the research design, the discussion suggests how self-governance is an effective way to increase privately-owned sustainable infrastructure.

2. Urban Infrastructure and Private Sector Participation

Providing incentives to private sector industries and businesses to adopt eco-friendly choices and invest in sustainable urban infrastructure has been a common approach of government [21]. Making businesses adopt new technologies for alternative fueling and deploy infrastructure at scale is a fast track for deep decarbonization. However, the change is likely to take a long time as considerable costs and investments have already been put into high-emitting infrastructure. Thus, industries see less motivation for change [21]. To address this issue, governments develop policies and programs that reflect the investment needs and demands of eco-friendly infrastructure [5]. The U.S. government has implemented an array of incentives, tax credits, loans and rebates to incentivize the private sector since 1988 with the Alternative Motor Fuels Act, which provided Corporate Average Fuel Economy incentives, and the American Recovery and Reinvestment Act of 2009 [4]. The incentive programs successfully stimulated auto industries to manufacture AFVs; however, the availability of alternative fuel infrastructure is not keeping pace with the increasing

number of AFVs and is lagging behind, with 5164 alternative fueling sites in 2005 and 22,929 in 2015, despite the policy efforts [4,22]. In terms of the type of alternative fuels, electric recharging stations were most common, followed by CNG and biodiesel, as shown in Figure 1, which depicts the distribution of fuel types in 2015 for privately owned stations.

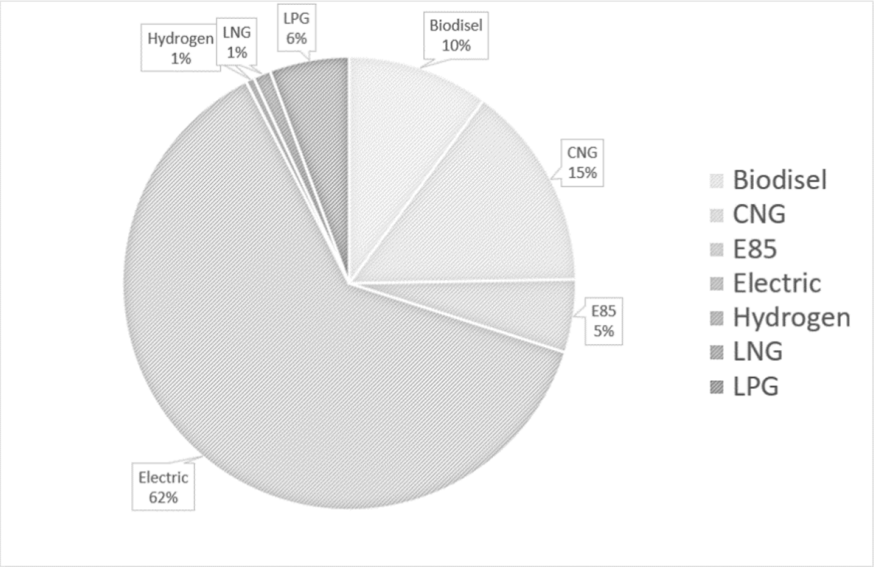

Figure 1. Alternative fuel types in 2015.

In addition to incentive systems, governments also take a collaborative approach to effectively govern alternative fuels. Collaboration has been considered as a solution for many environmental issues [23], to meet societal demands that the government cannot address solely. The federal government has cut aid for urban development and infrastructure since the 1970s, and local governments have been actively seeking new ways to finance developing infrastructure [11,12]. Especially for complex urban development, engaging the private sector has been a common method that local governments adopt. Accordingly, academia has developed multiple streams of discussions on collaborative governance, with the private sector to provide infrastructure. Among the approaches, public–private partnership (PPP) offers opportunities for businesses by letting them invest resources and harvest revenues, while local governments can save costs in providing public goods. PPP can be a solution to the increasing demand for various kinds of local infrastructure development as it can be designed to fit the local government context [12]. Local officials also prefer PPP as officials can enjoy more discretion than the command-and-control system of state or federal government's grants and aids [2,11,12,24,25]. Moreover, the voluntary environmental program (VEP) is a program, or an agreement, offered by the state or the federal government to let firms voluntarily reduce negative externalities on the environment by setting their own goals or becoming certified [26–28]. The Environmental Protection Agency (EPA) has adopted VEPs so that the private sector would choose more eco-friendly options, replacing regulatory policies [26,28,29].

At the same time, it has been observed that some local communities and stakeholders are voluntarily engaging in resource governance. Self-governance is where participants are the major users of the resources and are involved in making rules regarding the resources in an area. The possibility that users can find ways to govern resources independently from the regulation of the government was not recognized until the late 1990s [30]. The literature discusses how the private sector engages in self-governance. Networks of public and private actors play an important role in regional development that central authorities cannot reach; the private sector has "not only transformed into a potential co-governor but has also paved the way for the introduction of different market-like and civil society-like forms of self-governance into the public sector" [31] (p. 2).

While both PPP and VEP notice the role of the private sector in infrastructure governance, self-governance is distinctive from PPP or VEP. Self-governance operates based on the value of voluntary participation or self-regulation. On the other hand, PPP functions based on a contract that specifically designates the role that the private actor is expected to assume and, in most cases, PPP is adopted to draw financial resources for the implementation [32]. Moreover, VEPs do not necessarily value local governance and instead focus on allowing businesses to self-regulate themselves by setting feasible goals and collecting regular performance measures to demonstrate that the goals are being achieved [27].

While the literature recognizes the role of the private sector, very few studies examine how the private sector engages in self-governance voluntarily and builds a network with the public sector that may not promise direct financial returns. Fiack and Kamieniecki [33] describe how stakeholders from the private sector engage in climate change mitigation groups or networks at the local level but do not quantitatively examine whether this participation brings positive outcomes. This paper attempts to close the literature gap wherein not enough academic attention has been paid to self-governance and the role of the private sector in the governance of alternative fuels and infrastructure. It is necessary to study how the self-governance of alternative fuels affects the deployment of alternative fueling infrastructure in the private sector. More broadly, considering the imminence of decarbonization, it is pertinent to examine and assess the best practice to provide alternative fuel infrastructure. In doing so, this study will focus on the self-governance of alternative fueling infrastructure and the incentive systems given to the private sector for infrastructure investment.

3. Context: Clean Cities Program

This study focuses on the Clean Cities program which is a program to promote local-level self-governance networks. The Clean Cities coalitions program targets the reduction in petroleum usage to cut the amount of greenhouse gas emissions by implementing alternative fuels and improving fuel efficiency. In so doing, this program promotes the building of self-organized networks at the local level which focus on replacing fossil fuels, using alternative fuels and deploying fueling stations in local areas. The program launched in 1993 following the alternative fuel mandates from the Energy Policy Act in 1992 [34], and 125 local networks have been created nationwide.

Participants in local networks are private businesses, fuel providers, companies with vehicle fleets, state- and local-level government agencies and non-profit organizations who share an interest in reducing petroleum usage [35]. As described in Figure 2, the number of participating actors has increased from 2004 to 2015. Each network holds meetings and sets goals that the local network will pursue in consideration of local situations and markets. Based on mutual agreements, participants sign a Memorandum of Understanding which states the responsibilities and procedures needed to execute their objectives at the local level.

Furthermore, local networks do provide adequate incentives to the private sector. Based on market demand analysis, networks provide information on business and investment opportunities regarding alternative fuel and infrastructure. Moreover, the networks promote workplace fueling stations for private firms deploying refueling and charging stations in their businesses. To obtain shared goals, best practices and benefits are exchanged among participants for the successful governance of alternative fuel infrastructure. Private businesses not only gain technical assistance from the networks but also gain public recognition for being conscious of fuel efficiency through collaboration. Through the efforts of local networks, not only public organizations but also the private sector have been active in building fueling infrastructure [35].

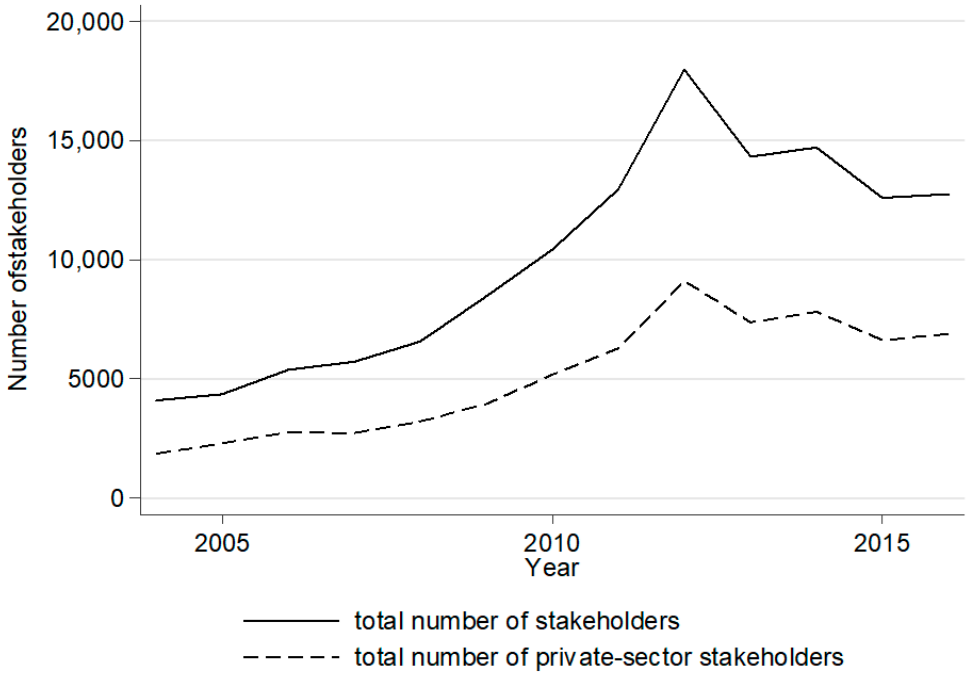

Figure 2. Number of stakeholders in Clean Cities nationwide (data source: U.S. Department of Energy).

4. Hypotheses: Self-Governance of Alternative Fueling Infrastructure

Governments facilitate the participation of diverse actors in public goods and service delivery, and this participation has directed academic attention to collaborative governance. Collaborative governance is defined as the process and structure that allows actors from different sectors to engage in the policy-making process [36–38] and to use their collective strength to conduct better work than the government alone could conduct. Spanning boundaries and obtaining the participation of actors outside the government can enable information exchange from multiple sources, encourage resource sharing and enhance the capacity to address public problems [36,39,40]. Therefore, multiple actors are brought into the problem-solving process, especially actors who are directly related to and have a stake in the problem.

As previous studies have revealed, self-governance is often effective in managing resources as well as infrastructure and in resolving collective action problems [41,42]. Studies demonstrate that self-governance arises when the expected benefits are clear to the participants [43,44]. Self-governance brings benefits such as allowing additional exchanges in the future and building positive reputations [39,45]. Self-governance arises from multiple actors in the public, private and third sectors at the local level to meet and work together [42,46]. Based on voluntary engagement, self-governance can reflect the interests of local-based stakeholders in the process of building governance [32,35]. In self-governance, actors develop rules on the roles and appropriations needed to manage resources [47]. Stakeholder participation enhances the legitimacy of government by building consensus and reflecting interests, thus making service delivery and policy implementation more effective [48].

Furthermore, self-governance complements the traditional top-down regulations in addressing environmental problems [39,49,50]. Environmental problems are challenging as one's behavior affects other parties who are not engaged in the operation. Business operations in a locality are likely to worsen the air quality and affect the community and other neighboring communities. Self-governance suggests ways to help stakeholders internalize externality costs voluntarily. Participants of self-governance monitor each other, and rules are more likely to fit the specific context of the local jurisdiction. If private actors

internalize externality costs without enforcement, then the transaction costs of imposing government regulations decrease for local governments. Governments design traditional regulations to monitor and enforce sanctions against businesses in the private sector. On the other hand, self-governance suggests a way to lower the enforcement and administration costs because participants replace the responsibility of government with self-enforcement.

Studies on the performance of collaborative governance suggest that change in behaviors or operations are considered outcomes of collaborative governance [39]. For example, Lubell and Fulton [51] measure the performance of collaborative governance by whether the governance changed the behavior of agricultural businesses to adopt sustainable practices. Therefore, the performance of Clean Cities can be examined by their adoption of alternative fuels and their supply of infrastructure. Based on the discussion, the first hypothesis posits that with self-governance in alternative fueling, the private sector is more likely to invest in alternative fueling infrastructure.

Hypothesis 1. *Collaborative governance is likely to increase the number of privately owned alternative fueling infrastructures.*

Furthermore, layers of government policies and programs exist to let private businesses engage in and provide public goods. Most commonly and effectively, incentive systems at the state level facilitate actors to engage in building sustainable infrastructure. Businesses in the private sector have fewer motivations to provide urban and sustainable infrastructure when they do not see financial benefits. Incentives offer positive payoffs to encourage behaviors that fit with policy goals and businesses will choose an alternative with a higher value to them [52]. Incentive systems allow choices where private actors can find potential returns by supplying alternative fueling stations. Then, it is important to see "whether the public sector has devised an activity that can help solve the problem", as Salamon and Lund [53] (p. 37) ask. The literature regarding alternative fueling stations also describes incentive programs for locating more alternative fueling stations that are in place under different contexts [15,18,54]. Yang et al. [15] acknowledge that tax policy may play a role in collaboration and in the private sector's engagement in the infrastructure provision of China. Still, it is hard to find studies that empirically examine whether these incentives are effective to install alternative fueling stations. Fang et al. [14] show that subsidy and taxation policies have positive effects on deploying electric charging stations in China. Therefore, it would be meaningful to test whether these arrays of incentive systems are effective to provide sustainable infrastructure, which leads to the second hypothesis:

Hypothesis 2. *State-level incentives are likely to increase the number of privately owned alternative fueling infrastructures.*

5. Data, Measures and Methods

The analysis focuses on alternative fueling infrastructure from 2004 to 2015 in 997 counties in 12 states in the United States: California, Texas, New York, Connecticut, Florida, Colorado, Illinois, Louisiana, Michigan, North Carolina, Ohio and Tennessee. To test the hypotheses, this study constructs a dataset merging data from different sources, including the Department of Energy (DOE), the Alternative Fuels Data Center (AFDC), the National Renewable Energy Laboratory (NREL), the County Business Patterns, the U.S. Energy Information Administration and the Census Bureau.

Specifically, the dependent variable for this study focuses on the alternative fueling stations that are privately owned. Alternative fuel infrastructure makes a good measure of the outcome of Clean Cities because it is one of the goals that the governance pursues. While there are environmental needs and increasing demands for alternative fueling infrastructure, the scarcity of retailers who carry alternative fuel was a persistent problem [55] and the public sector cannot be the sole provider of sustainable infrastructure. Businesses in the private sector who voluntarily participate in reducing environmental damage and in local efforts to govern the resource are then necessitated. By studying how much private

fuel suppliers and retailers engage in alternative fueling instead of traditional fueling, the outcome of the Clean Cities collaboration can be observed. Following the definition of DOE and NREL, alternative fueling stations refer to the refueling and recharging sites of ethanol, biodiesel, compressed natural gas, electric, hydrogen, liquefied natural gas, renewable natural gas and propane. The number of stations in each county was recorded yearly based on the establishment date information. Especially, AFDC offers information as to whether the alternative fueling infrastructure is owned by public, private businesses or utilities. Based on the information, a count variable of privately-owned alternative fueling infrastructure at county level is created.

The Clean Cities network is a binary variable that measures the existence of local Clean Cities networks in a county. The variable codes whether the county has a network or is under the geographical coverage of a network. If a network has expanded or disorganized over time, the changes are also recorded. The DOE and NREL provide data for all Clean Cities networks that have existed or are existing across the nation.

A set of count variables are created capturing the number of incentive programs offered to alternative fueling infrastructure owners for loans, rebates and tax credits. These incentives and regulations directly affect the provision of the businesses' alternative fueling stations, which should be isolated from the effect of Clean Cities networks on the outcome. While these programs incentivize the private sector with a monetary approach at the state level, Clean Cities networks emphasize collaboration and voluntary changes at the local level over the energy and transportation sector. Thus, both variables are expected to lead to more sustainable infrastructure. The data were obtained from AFDC.

The supply of alternative fueling stations is likely to be affected by market-driven factors. Market-side factors that can affect the outcomes are also included. First, the number of enterprises in an industry that have high-volume fleet usage is considered in the model. The variable measures the number of enterprises in the local general freight trucking industry, which is likely to create a demand for local fueling stations. The data was collected from the County Business Patterns, using NAICS code 48411, which is the local general freight trucking industry. Second, the average price of the main energy resources of coal, natural gas, petroleum and wood, at the state level, is accounted for. The unit of the data is USD per million BTU, and it captures the average price at the state level. The data is from U.S. state energy data by U.S. Energy Information Administration. Third, carbon dioxide emission in energy-related facilities at the state level is included, which may affect the demand for AFVs as well as stations. The data were obtained from the U.S. Energy Information Administration.

Furthermore, population, median household income, number of sustainable electric power generation facilities and total debt outstanding at the county level that may affect the variation in number of alternative fuel stations are controlled. County population and median household income are from the U.S. Census Bureau. The sustainable electric power generation facilities variable measures the number of hydroelectric, solar, wind, geothermal and biomass electric power generating utilities to capture how much the county is dedicated to sustainability in general. The data are from the County Business Patterns. Carbon dioxide emission at the state-level in energy-related facilities data are from the U.S. Energy Information Administration. The total county government debt outstanding represents the resource slacks that the local government owns, and if the local government lacks resources, environmental problems are likely to have low priority [56,57]. In this case, the number of privately-owned alternative fuel companies is likely to increase. The data were obtained from the Historical Finances of County Governments, but the information was not provided for some counties and only 7090 observations were available. Table 1 describes the variables and measurements in detail.

Table 1. Description of variables (unit of analysis: county).

	Measurement
Dependent variable	
Privately-owned alternative fueling infrastructure	Number of privately-owned alternative fuel stations in the county
Independent variables	
Clean Cities	Clean cities operating in each county (yes = 1)
Incentive system: Laws and incentives	Annual number of incentive systems of loan, rebate, grant and tax credit: State-level incentives that are given to alternative fueling infrastructure
Control Variables	
Industry density: regional concentration of industry with high car-fleet usage	Number of enterprises in industries with high volume of fleet usages in one county NAICS 48411: General Freight Trucking, local
Main energy resource price	The average price of main energy resource at state
Energy-related carbon dioxide emissions	Energy-related carbon dioxide emissions at state level
Sustainable electric power generation facilities	Number of hydroelectric, solar, wind, geothermal, biomass electric power generation facilities (NAICS 221111, 221114, 221115, 221116, 221117) at county level
Total debt outstanding	Amount of total debt outstanding, 1000 USD
Household income	Median household income at county level
Population	Population at county level

The research questions are tested with panel fixed-effects Poisson regression models, where the number of privately-owned alternative fueling infrastructures is the dependent variable. Fixed-effects panel regression models are used here because there exist unobserved individual effects for each county that are correlated with the observed effects, where the random effects estimator can be inconsistent. Moreover, the fixed effect approach does not make assumptions regarding the county-specific intercepts, and the estimated coefficients are within the effects. Counts of the dependent variable take a wide range since 40% of the counts are zero. The mean number of the privately-owned station is 0.9855 with a variance of 13.6986, so the data are highly over-dispersed. The between standard deviation (2.6018) is similar to the within standard deviation (2.6335); the 12-year average number of privately owned stations per county varies, with the lower quartile 0, an upper quartile of 3.7387 and the median 0. Therefore, since over-dispersion exists across and between counties, it is possible that the inclusion of individual effects greatly reduces over-dispersion [58]. To correct over-dispersion, this study adopts the panel fixed-effects Poisson model which controls individual fixed effects [59,60]. Time dummies are included to control for the tendency toward an increasing number of stations over time (from an average of 0.0832 in 2004 to 2.9398 in 2015).

Suppose the number of privately-owned alternative fueling infrastructure of the *i*-th county at the *t*-th year follows a Poisson process with parameter λ_{it} taking the form $\lambda_{it} = exp(X_{it}\beta + \delta_i)$, where δ stands for a county fixed effects; X is a set of explanatory variables associated with the *i*-th county at period *t*, which includes Clean Cities collaborative governance, incentive programs, government's total debt outstanding, intensity of high fleet usage industry, sustainable power generation facilities, median household income, population, average price of primary fuels and carbon dioxide emission. Equation below is the model to be estimated to identify the effect of Clean Cities governance on privately-owned infrastructure controlling other variables.

$$\ln(\text{Infrastructure}_{it}) = \beta_o + \delta_i + \omega_t + \beta X_{it} + \mu_{it}$$

From the equation, ω denotes time series fixed effects and μ stands for the error term.

6. Results

Table 2 summarizes the descriptive statistics of the pooled-data variables. The descriptive statistics table that reports the means and standard deviations of the full panel data variables from 2004 to 2015 that are used for hypothesis testing is in Appendix A.

Table 2. Descriptive statistics.

	N	Mean	SD	Min	Max
Clean Cities	11,964	0.4433	0.4970	0	1
Privately owned stations	11,964	0.9855	3.7012	0	75
Incentive: loans	11,964	0.0889	0.3001	0	2
Incentive: rebate	11,964	0.0316	0.1991	0	2
Incentive: grant	11,964	0.3438	0.6083	0	2
Incentive: tax	11,964	0.2052	0.4818	0	2
Median household income	11,964	43,776.06	11,111.72	17,843	109,926
Population	11,964	10.6684	1.4918	6.440947	15.47445
Average price of primary fuels	11,964	10.6025	1.9556	7.4	17.72
High fleet use industry	11,964	12.9384	47.3818	0	1647
Sustainable power generation facilities	11,964	0.2609	0.9489	0	20
Carbon dioxide emission	11,964	294.9203	189.5735	34.12	649.59
Total debt outstanding	7090	258,157.4	909,080.7	0	17,500,000
Year	11,964	2009.5	3.4522	2004	2015

Alternative fueling infrastructures are not only privately owned, but also public organizations and local utilities own some of the infrastructures. Examining utilities- and public-owned alternative fueling infrastructure provides a better description on the landscape of local alternative fueling infrastructure governance and how much the private sector is contributing to the supply of infrastructure.

Observing the dynamics of alternative fueling infrastructure from 2004 to 2015 provides a better understanding of the deployment of alternative fueling infrastructure. Figure 3 shows the number of private-, utilities- and public-owned alternative fueling stations. The number of utilities-owned and public-owned stations are measured at county level each year. Public organizations, including federal, state and local governments, were a major actor for the early setout of alternative fueling infrastructure. While the public sector had more stations in 2004, after 2010 the number of privately owned stations increased at a fast pace and outnumbers other sectors in providing infrastructure in 2015. Local utilities which generate electricity or provide natural gas, water and other resources also play a role in facilitating alternative vehicle adoption as well as supplying alternative fueling infrastructure [61].

Table 3 provides a broader picture of the increasing trend of privately-owned alternative fueling stations across states. The table is created by aggregating the number of county level privately-owned alternative fueling infrastructure in each state from 2004 to 2015. While many businesses entered the alternative fuel market in California and Illinois early in 2004, some others did not have any private businesses that operated with an alternative fuel supply. Still, the number of alternative fueling stations has been generally increasing across the 12 states.

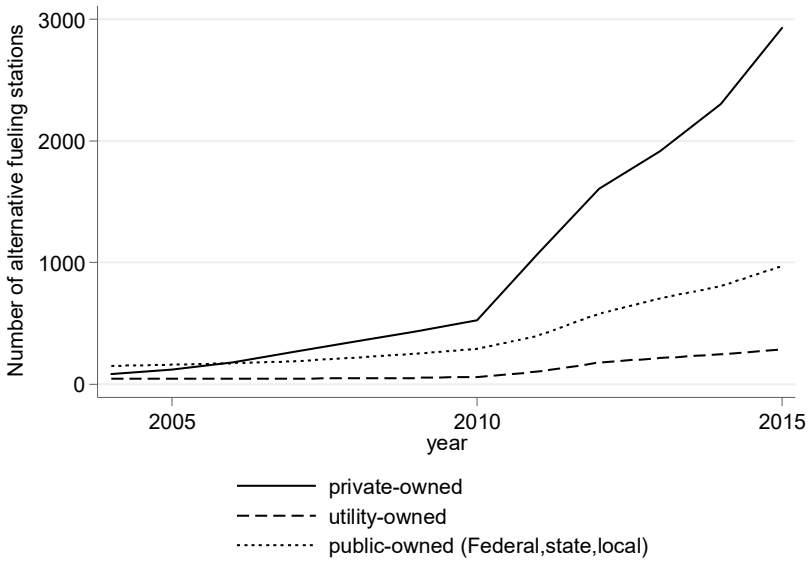

Figure 3. Number of alternative fueling stations by ownership.

Table 3. Number of privately-owned alternative fueling stations by state.

State	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
California	52	55	62	63	82	102	117	263	319	410	478	697
Colorado	4	5	6	22	36	43	46	52	92	110	137	172
Connecticut	1	1	1	1	3	4	10	50	77	90	118	131
Florida	0	2	2	2	2	4	10	59	133	158	183	249
Illinois	9	31	47	58	71	81	86	108	196	225	255	292
Louisiana	1	1	1	1	1	1	1	4	33	37	42	46
Michigan	2	5	20	38	50	69	80	116	146	183	231	276
North Carolina	0	0	0	1	9	24	38	121	133	161	178	209
New York	2	5	6	7	8	9	12	31	94	105	129	166
Ohio	3	4	12	36	47	50	53	76	144	169	226	272
Tennessee	1	1	3	10	14	17	28	77	85	93	103	119
Texas	8	11	18	27	28	32	44	115	155	174	226	302

Next, this article tests whether self-governance is effective to increase privately-owned infrastructure. The fixed effects Poisson regression model results are shown in Table 4, which reports the incidence-rate ratio for interpretation purposes. The models are estimated with the numbers of privately-owned alternative fueling stations the dependent variable in a county in each model. Model 1 is the simple model with the Clean Cities variable, Model 2 includes state incentives and Model 3 includes all control variables. The results of Model 3 will be used here for interpretation. The reported panel robust standard errors correct for over-dispersion and autocorrelation [58] and all models include year dummies. Across the three models, the results suggest that collaborative governance is a way to address the deficit of infrastructure, supporting Hypothesis 1. The Clean Cities self-governance is associated with an estimated 28.47% increase in the incidence rate in Model 3 for the given values of the other covariates. This supports previous studies that suggested self-governance can be an effective way to find a solution for environmental issues and draw out better outcomes [30]. The results suggest that these cross-sector collaboration networks can be effective to stimulate the private sector to provide public goods [31].

Table 4. Poisson fixed effects estimates (DV: privately owned alternative fueling stations).

	DV: Number of Privately Owned Alt. Fuel Stations		
	(1)	**(2)**	**(3)**
Clean Cities coalitions dummy	1.3566 **	1.3186 **	1.2847 *
	(0.1970)	(0.1817)	(0.1831)
Incentive: loans		1.0720	1.1228 **
		(0.0600)	(0.0611)
Incentive: rebate		0.9328	0.8452
		(0.1043)	(0.0956)
Incentive: tax credit		1.0127	1.1362 *
		(0.0677)	(0.0817)
Incentive: grant		0.8452 ***	0.7974 ***
		(0.0497)	(0.0564)
Total debt outstanding			1.0000 *
			(0.0000)
High fleet use industry			0.9999
			(0.0002)
Sustainable power generation facilities			1.0111
			(0.0107)
Median household income			1.0000 ***
			(0.0000)
Population			5.9139
			(6.4451)
Average price of primary fuels			1.067 **
			(0.0328)
Carbon dioxide emission			0.9990
			(0.0019)
Year fixed effects	Yes	Yes	Yes
Observations	5364	5364	3959
Number of county	447	447	381
Pseudo likelihood	−4455	−4444	−3546
Wald Chi2	1936	2539	3248
Prob > Chi2	0.0000	0.0000	0.0000

Reports incidence-rate ratio; robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

For state incentives, loan and tax credits are associated with an estimated 12.28% and 13.62% increase in the incidence rates, respectively. The results reveal that direct financial incentives to the private sector can be associated with increasing the private sector's engagement in supplying alternative fueling infrastructure, which has been implemented by most of the state governments and supports Hypothesis 2.

Average fuel price is positively associated with the private sector provision of fueling infrastructure which is significant. This adds evidence to the literature, which finds that regulating alternative fuel prices to be cheaper than gasoline prices is effective in increasing the number of alternative fueling stations [62]. Market demand for fuels measured with the intensity of high fleet use industry or sustainable power generation in the county do not have significant effect on the alternative fueling stations. On the other hand, total debt outstanding and income of county have a positive relationship with the privately-owned alternative fueling stations. The results comport with the previous studies that find that when local governments do not have enough fiscal capacity to implement sustainability [63], the private or third sector are likely to engage in supplying infrastructure [2]. Moreover, the results confirm that access for alternative fuels and sustainability are related to the income level which previous studies reveal [64].

As an auxiliary analysis, this paper estimates the same models using the number of utility-owned alternative fueling stations as the dependent variable (see Appendix A). The data from the AFDC does not specify whether the utility is privately or public owned, but a substantial number of private utility companies own fueling stations in the dataset. Therefore, it is meaningful to test whether self-governance and incentives are also positively

related to utility-owned fueling infrastructure. The results are similar to the estimates on privately-owned infrastructure; self-governance and loan incentives are positively associated with utility-owned infrastructure.

7. Discussion

The results of this study expand two streams of literature, collaborative governance and incentive systems of supplying sustainable infrastructure. First, the results provide evidence that collaborative governance studies need to focus on how each actor engaged contributes to the goal of the governance. Extant studies of collaborative governance paid more attention to citizens, community groups and non-profits as the main participants and contributors in self-governance from the non-governmental sector [65]. On the other hand, multiple actors engage in Clean Cities collaborative governance, including private businesses, local governments, agencies, non-profits and researchers. Measuring the performance of collaborative governance can be more complex than studying the performance of one organization [39,66]. Therefore, collaborative governance studies should also pay attention to the role of the private sector and how they perform. As the literature on self-governance asserts, collaborative governance of actors across diverse sectors can create synergetic effects and achieve better outcomes [67]. Moreover, the result empirically supports previous studies that private businesses play a key role to supply infrastructure for sustainability [2]. The results that private businesses collaborate with local actors to govern resources expands the discussion on the role of businesses in local sustainability, comporting with the literature that businesses exert an influence over the policy decision-making process of local governments' efforts at sustainability [68].

Furthermore, the results help advance research on the effectiveness of incentive systems in providing alternative fuels, which vary in types across the states and local governments. For example, local governments in Florida offer financing to property owners who install electricity fueling stations on their property and Louisiana state offers an income tax credit of 30% of the cost of purchasing a property that delivers alternative fuels. Loan incentive programs with low interest rates and tax credit programs have proven to be effective in promoting alternative energy in general, and the result provides evidence that financial incentives are effective to provide alternative fueling infrastructure [14,55,69]. The findings of this research align with most of the extant studies which focus on the effectiveness of monetary incentives to build a sustainable transportation system, especially when complementary incentives are bundled together [14,62]. The results also support that a set of incentives complement one another and is effective for businesses to engage in sustainability. The literature finds that one single financial incentive may not have a significant impact on renewable energy technology adoption, but that a bundle of financial incentives is effective to deploy alternative fueling infrastructure [70]. Moreover, the results reveal that self-governance as a non-regulatory and alternative approach can be effective. A traditional approach to enforce eco-friendly operation of the private sector and govern public goods was through regulation, along with employing financial incentive programs [71]. Innovative and alternative approaches can be effective to replace traditional approaches that can be costly for local governments.

8. Conclusions

This research has several important policy implications for current discussions about alternative fueling infrastructure and sustainability. First, self-governance is effective in allowing the private sector to engage in achieving collective goals. When resources are governed by diverse entities who are direct users, synergy can occur and the governance can be more effective [67]. Self-governance was widely discussed as being successful for governing resources and addressing collective action problems as well as complementing traditional policy incentives [72,73]. However, not many studies focused on whether collaborative governance impacts the behavior of local stakeholders of private businesses.

This study reveals a positive relationship between collaborative governance and the private sectors' engagement in providing alternative fueling infrastructure.

Second, this study provides evidence that both self-governance and financial incentive systems are effective to provide sustainable infrastructure. It is a common approach for governments to arrange multiple layers of incentive systems to obtain policy goals as well as provide infrastructure [2]. Admittedly, there is a high chance that financial incentives would be a strong driving force for the private sector as the businesses operate for profit maximization. However, the results suggest that building networks, outreaching and the network's technical assistance can be effective for private businesses to make the transition to alternative fueling supply and phase out fossil fuel in the business operation. The results demonstrate that Clean Cities can be a strategic choice for federal agencies to build more alternative fueling infrastructure and enhance the connectivity of alternative fueling vehicles [7]. Moreover, collaborative governance can be effective when the local government lacks enough of a budget to incentivize businesses financially to participate in providing alternative fueling infrastructure. Still, the author is cautious in generalizing the results to different contexts. Some of the incentives were effective in the U.S. case in this study and a simulation study conducted in the context of China showed that incentives can be effective [14]. However, another study revealed that the incentive system was not found to be effective, which calls for further investigation [62].

This study is not without limitations. First, further conceptual differentiation between PPP and self-governance is required to build a better understanding of private sector engagement in resource governance and urban management. This study understands self-governance as where the private sector's actors engage voluntarily and build a network with other actors across the sectors with a common goal. However, some studies define self-governance as a broader concept and that PPP is a type of self-governance in which the private sector engages. A deeper examination of the motivation of private firms and industries that participate in self-governance and PPP, studying whether they are just self-interested or act out of social responsibility, can provide some insights into urban infrastructure management. Second, the expanded use of alternative fuels is likely to be driven both by the suppliers and the users. While most of the academic attention regarding alternative fuels has been to understand the behaviors and decisions of AFVs, this study has its own merit by focusing on infrastructure. Deploying alternative fueling stations is likely to be market driven, including the alternative fuel price or location [14] to cater to the exact needs of AFV owners. Moreover, another study points out that AFVs and the alternative fueling infrastructure are likely to be in a relationship of co-evolution which indicates that the study of alternative fueling infrastructure should consider the existence of AFVs [74]. While this study controls for potential market demand, it could not consider the exact AFVs market demand for each county due to limited data availability.

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Appendix A

Table A1. Panel data summary statistics.

Variable		Mean	SD	Min	Max	Observations
Privately-owned alt. fuel stations	overall	0.9855	3.7012	0	75	N = 11,964
	between		2.6018	0	24.9166	n = 997
	within		2.6335	−20.9311	53.6522	T = 12
Utility-owned alt. fuel stations	overall	0.1147	0.7154	0	20	N = 11,964
	between		0.5105	0	6.8333	n = 997
	within		0.5105	−5.7187	13.2813	T = 12
Public-owned alt. fuel stations	overall	0.4093	1.7842	0	42	N = 11,964
	between		1.4310	0	17.1666	n = 997
	within		1.0665	−13.7574	25.2426	T = 12
Clean Cities coalitions dummy	overall	0.4432	0.4968	0	1	N = 11,964
	between		0.4903	0	1	n = 997
	within		0.0816	−0.3901	1.2764	T = 12
Incentive: loans	overall	0.0889	0.3001	0	2	N = 11,964
	between		0.1724	0	0.5	n = 997
	within		0.2457	−0.4110	1.8389	T = 12
Incentive: rebate	overall	0.0316	0.1991	0	2	N = 11,964
	between		0.1321	0	0.5833	n = 997
	within		0.1490	−0.5517	1.4482	T = 12
Incentive: tax credit	overall	0.2052	0.4818	0	2	N = 11,964
	between		0.3845	0	1.1666	n = 997
	within		0.2906	−0.9614	1.0385	T = 12
Incentive: grant	overall	0.3438	0.6083	0	2	N = 11,964
	between		0.4920	0	1.75	n = 997
	within		0.3581	−1.4062	1.5104	T = 12
Total debt outstanding	overall	258,157.4	909,080.7	0	17,500,000	N = 7090
	between		701,342.6	0	13,900,000	n = 977
	within		196,368.3	−4,162,831	3,841,913	T-bar = 7.25691
High fleet use industry	overall	12.9384	47.3818	0	1647	N = 11,964
	between		46.5690	0	1153.083	n = 997
	within		8.8519	−368.145	506.8551	T = 12
Sustainable power generation facilities	overall	0.2609	0.9489	0	20	N = 11,964
	between		0.7892	0	9.4167	n = 997
	within		0.5273	−8.1558	10.8442	T = 12
Median household income	overall	43,776.06	11,111.72	17,843	109,926	N = 11,964
	between		10,543.41	22,809.5	98,969.08	n = 997
	within		3522.638	24,183.4	66,225.31	T = 12
Population	overall	10.6684	1.4918	6.4409	15.4744	N = 11,964
	between		1.4920	6.5110	15.4662	n = 997
	within		0.0371	10.2362	11.00055	T = 12
Average price of primary fuels	overall	10.6025	1.9556	7.4	17.72	N = 11,964
	between		1.4206	8.8891	14.09	n = 997
	within		1.3447	7.6424	14.6391	T = 12
Carbon dioxide emission	overall	294.9203	189.5735	34.12	649.59	N = 11,964
	between		188.9022	37.9291	607.8992	n = 997
	within		16.9376	237.1311	336.6111	T = 12
Year	overall	2009.5	3.4521	2004	2015	N = 11,964
	between		0	2009.5	2009.5	n = 997
	within		3.4521	2004	2015	T = 12

Table A2. 12 states with coalitions in 2015.

State	Number of Coalitions	Region	Counties	With Coalitions	No Coalitions
California	14	Southwest	58	25	33
Texas	10	South Central	246	41	205
New York	7	Northeast	62	40	22
Connecticut	6	Northeast	8	5	3
Florida	5	Southeast	67	24	43
Colorado	3	Northwest	64	63	1
Illinois	3	North Central	102	5	97
Louisiana	3	South Central	60	49	11
Michigan	3	North Central	83	8	75
North Carolina	3	Southeast	98	22	76
Ohio	3	Mid-Atlantic	85	81	4
Tennessee	3	Southeast	90	85	5

Table A3. Panel Poisson model results (DV: utility owned alternative fueling stations).

	DV: Number of Utility Owned Alt. Fuel Stations		
	(1)	(2)	(3)
Clean Cities coalitions dummy	2.4816 ***	1.8446 **	1.9157 ***
	(0.7079)	(0.4809)	(0.4128)
Incentive: loans		1.5620 ***	1.9407 ***
		(0.1606)	(0.2920)
Incentive: rebate		0.1850 ***	0.1660 ***
		(0.0293)	(0.0295)
Incentive: tax credit		0.5009 ***	0.4296 ***
		(0.1086)	(0.1067)
Incentive: grant		1.3107	1.3646
		(0.2467)	(0.2887)
Total debt outstanding			1.0000
			(0.0000)
High fleet use industry			1.0001
			(0.0004)
Sustainable power generation facilities			0.9503 **
			(0.0191)
Median household income			1.0000 ***
			(0.0000)
Population			6.8543
			(8.9496)
Average price of primary fuels			0.8996
			(0.0622)
Carbon dioxide emission			0.9811 **
			(0.0080)
Year fixed effects	Yes	Yes	Yes
Observations	1296	1296	1154
Number of county	108	108	102
Pseudo likelihood	−978.4315	−881.2763	−799.4
Wald Chi test	214.1387	464.9518	1341
Prob > Chi2	0.0000	0.0000	0

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$

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