Effects of Charging Infrastructure on Electric Vehicles Adoption and Transportation Emissions in the United States: A Panel Analysis

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Outline

Research Questions

- What is the effect of EV charging infrastructure on EV adoption?
- What is the effect of EV charging infrastructure on carbon emissions?

Introduction: Emission Problem

In the United States, transportation is one of the fastest-growing sources of emissions (Larina et al., 2021; Pamucar et al., 2021).

Transportation was the largest contributor to U.S. greenhouse emissions in 2021 (contributed 29%) of the total emissions, and Light–Duty vehicles (passenger cars, light-medium trucks) contributed 58% of the total transport sector emissions in 2021, (EPA,2021).

The argument is that emissions from electric vehicles are relatively lower than emissions from gasoline vehicles (Zhao et al., 2022a).

Introduction: Emission Problem Contd

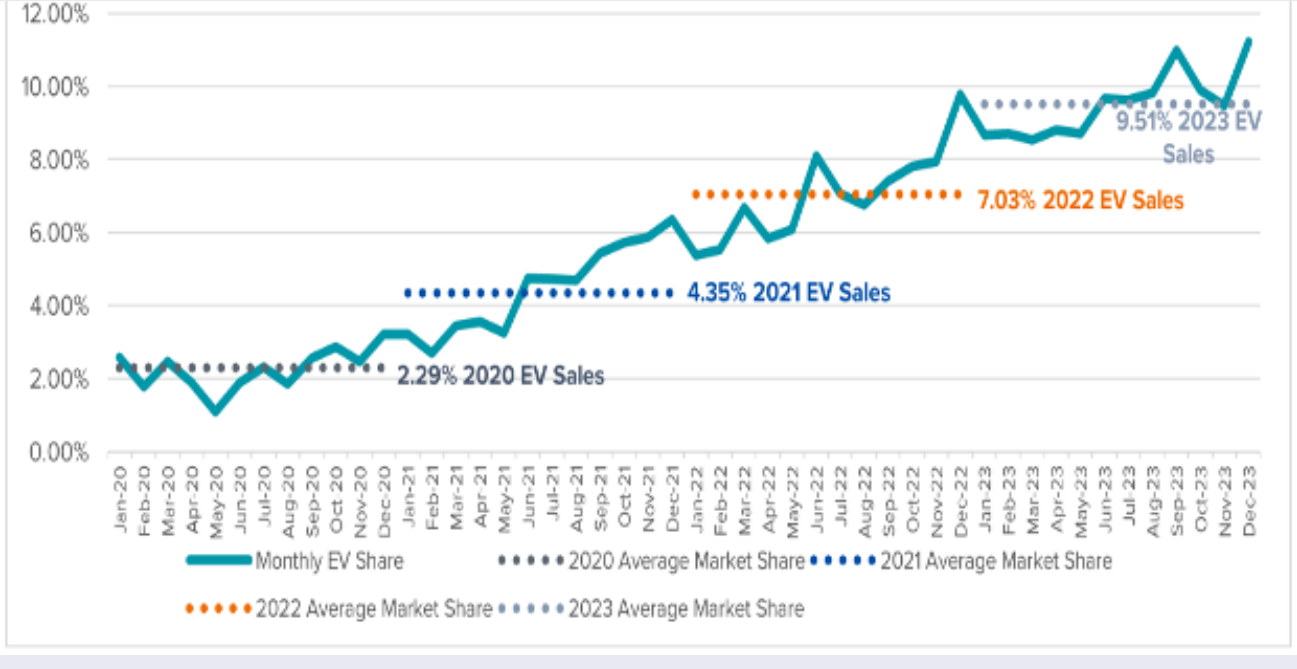
- Green Transportation policies including **expanding EV Charging Infrastructure, Alternative Fuel Station, and tax incentives** for purchasing electric vehicles (EVs) are commonly used.

For example, the Biden-Harris Administration in January, 2024 announced **$623 million in grants to help build out an electric vehicle (EV) charging network across the U.S**.

"The goal is to building out a convenient, affordable, reliable and made-in-America national network of EV chargers, including at least 500,000 publicly available chargers by 2030 ensuring that EVs are made in America." (FHA, 2024)

Introduction: EV Adoption and Infrastructure Problem

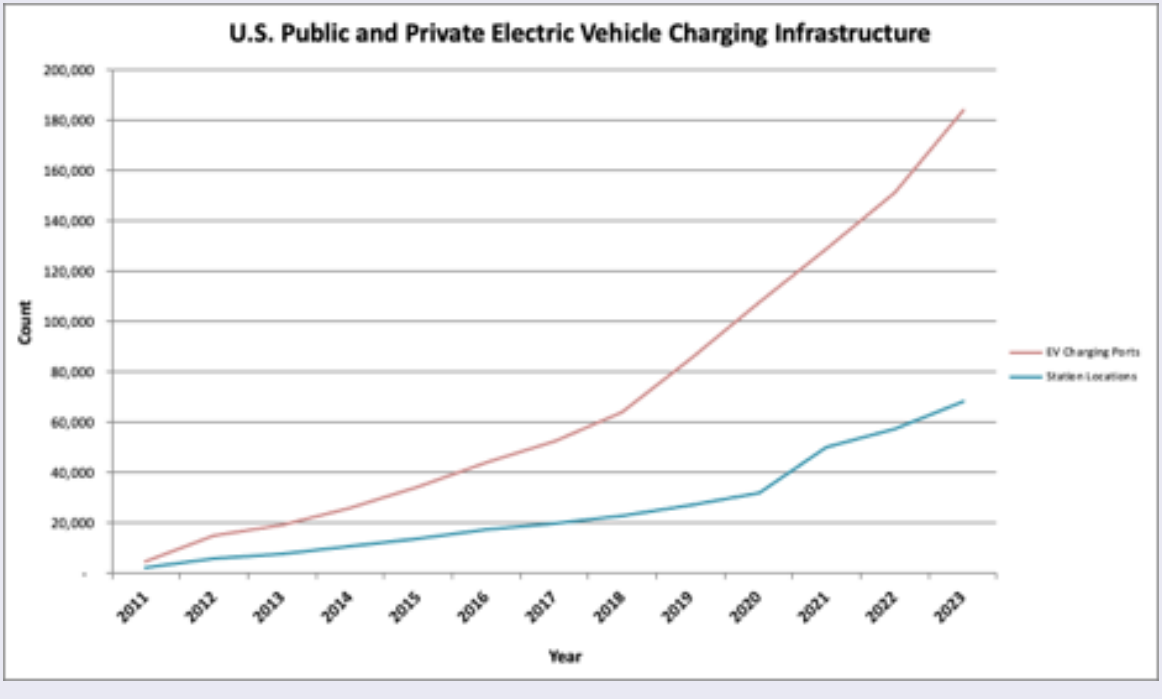
Figure 1: USA – EV Market Share (Sales) 2020 to 2023



source: Alliance for Automotive Innovation, 2023

EV Adoption and Infrastructure Problem Contd

Figure 2: USA - Public and Private Charging Infrastructure

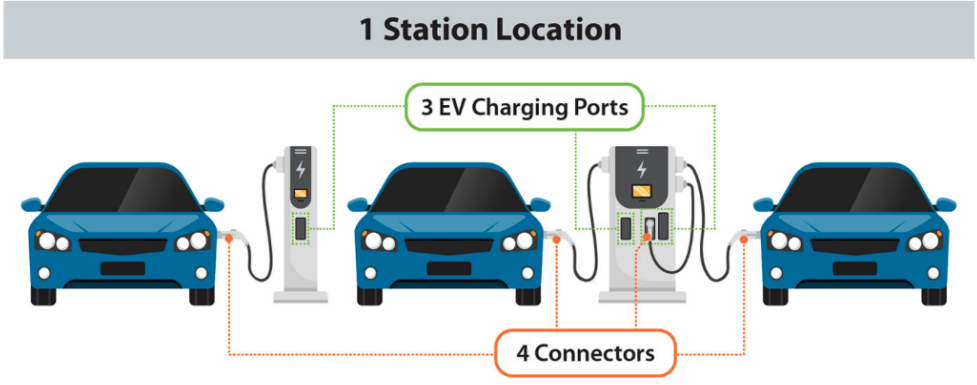


source: Alternative Fuel Data Center, 2023

EV Adoption and Infrastructure Problem Contd

Figure 2.1: Charging Station and Charging Ports

- **Station Location:** A station location is a site with one or more EV charging ports at the same address. Examples include a parking garage or a mall parking lot.
- **EV Charging Port:** An EV charging port provides power to charge only one vehicle at a time even though it may have multiple connectors. The unit that houses EV charging ports is sometimes called a charging post, which can have one or more EV charging ports. EV charging ports are also sometimes referred to as electric vehicle supply equipment (EVSE) ports.
- **Connector:** A connector is what is plugged into a vehicle to charge it. Multiple connectors and connector types (such as CHAdeMO and CCS) can be available on one EV charging port, but only one vehicle will charge at a time. Connectors are sometimes called plugs.



source: Alternative Fuel Data Center, 2023

EV Adoption and Infrastructure Problem Contd

Figure 3: EV Sales Market Share by State in 2023

2023 (Full Year) EV Market Share by State

1	CA*	25.71%	11	VT*	10.32%	21	GA	7.39%	31	KS	4.79%	41	MT	3.40%
2	DC	19.63%	12	CT*	10.19%	22	NC	7.03%	32	ID	4.75%	42	KY	3.34%
3	WA*	18.79%	13	VA*	9.73%	23	MN*	6.37%	33	OK	4.74%	43	IA	3.16%
4	OR*	15.42%	14	AZ	9.39%	24	PA	6.34%	34	WI	4.26%	44	AL	2.57%
5	CO*	15.14%	15	NY*	9.06%	25	TX	6.20%	35	OH	4.23%	45	AR	2.26%
6	NJ*	13.59%	16	DE	8.78%	26	ME*	6.05%	36	IN	4.13%	46	SD	2.12%
7	NV*	13.23%	17	UT	8.73%	27	MO	5.95%	37	MI	4.00%	47	WY	2.11%
8	MA*	12.04%	18	IL	7.80%	28	NH	4.91%	38	SC	3.88%	48	LA	1.98%
9	MD*	11.70%	19	RI*	7.75%	29	NM	4.89%	39	NE	3.72%	49	WV	1.77%
10	HI	11.01%	20	FL	7.43%	30	TN	4.88%	40	AK	3.58%	50	MS	1.53%
												51	ND	1.28%

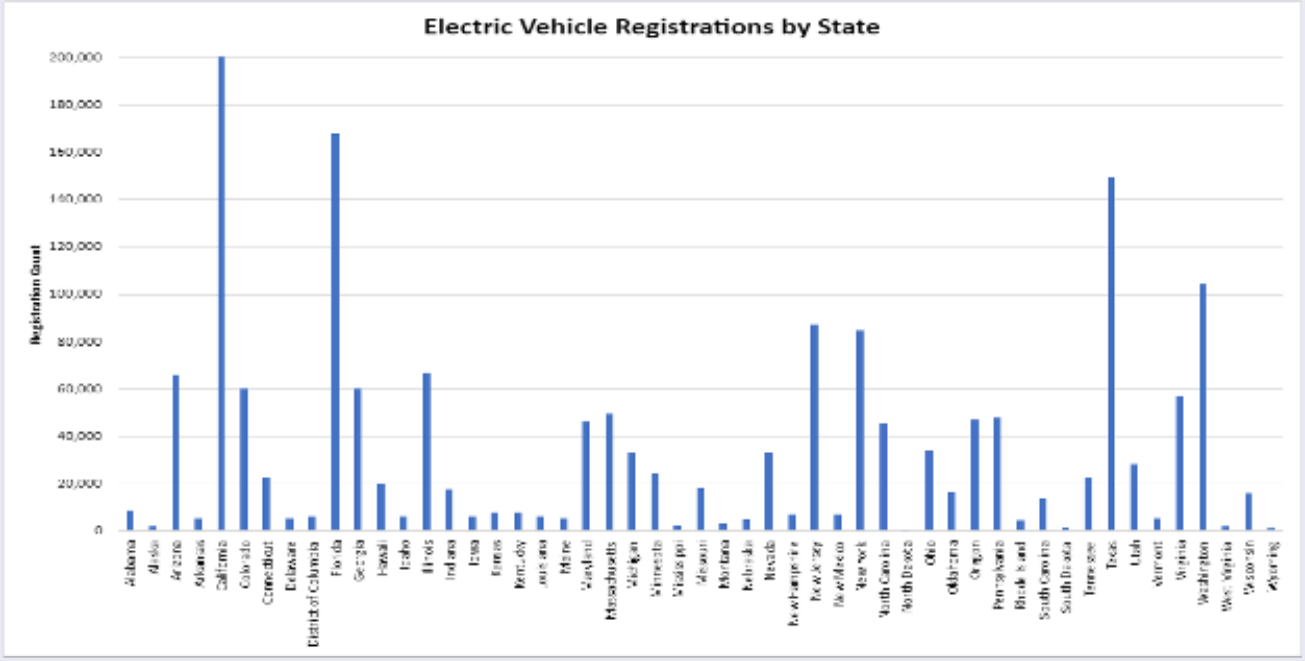
[8] Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering January 1, 2021 – September 30, 2023
[9] *Denotes states that have adopted California's ZEV program

source: Alliance for Automotive Innovation, 2023

EV Adoption and Infrastructure Problem Contd

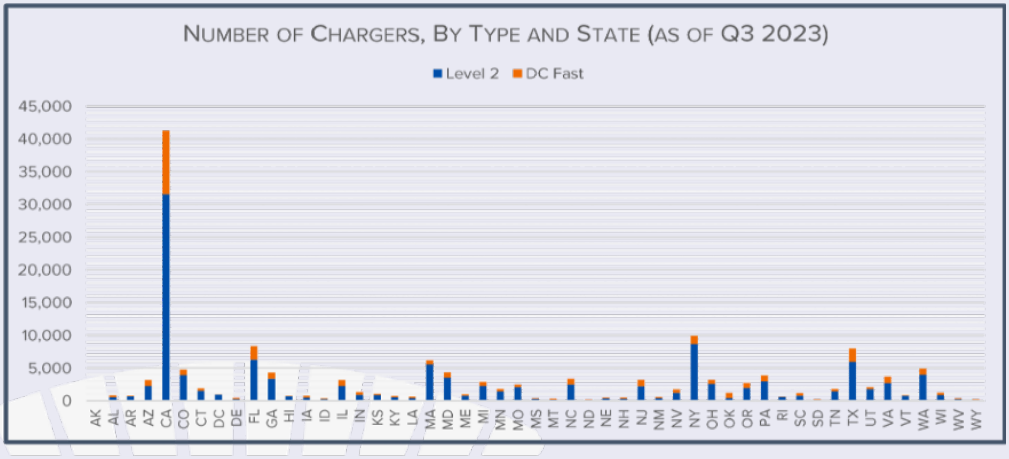
EV Registration is unevenly distributed across States

Figure 4: EV Registration by States as of 2022



EV Adoption and Infrastructure Problem Contd

Figure 5: Number of Charging Stations by States.



source: Alliance for Automotive Innovation, Electric Vehicle Report, Q4 2023

Notes: Level 1 - approximately 5 miles of drive per 1 hour of charging.

Level 2 - approximately 25 miles drive per 1 hour of charging.

DC Fast Charging - approximately 100 to 200 miles drive per 30 min charging.

Why these Research Questions?

EVs are estimated to reduce emissions by 70–85% by 2030 (Tran, 2012.)

It is evident that EV Adoption is increasing but we do not know to what extent is charging infrastructure driving EV adoption.

EV Adoption could reduce emission but it is unclear the extent to which charging infrastructure could affect emission reduction.

- What is the effect of EV charging infrastructure on EV adoption?
- What is the effect of EV charging infrastructure on carbon emissions?

Methodology

Data: Sources and Measurement of Variables

Variable	Measurement	Source
Transportation Carbon Emission (Em_{it})	Total gasoline consumption (millions of gallons)/population (millions)	**Gas Cons:** Federal Highway Administration (FHA)
		Population: US Census Bureau.
EV[i] Share $(EVshare_{it})$	Light Duty EVs[ii]/ All Light Duty Vehicles (LDV) registered	**Registered EVs:** Alternative Fuel Data Center (AFDC)
		Total registered Vehicles (all light-duty vehicles): Federal Highway Administration (FHA)
Charging [iii]Infrastructure $(INFRS_{it})$	Number of Electric Vehicles Charging Ports (public and private)/ Ten thousand population in a state	**Number of Charging Ports:** Alternative Fuel Data Center (AFDC)
		Population: US Census Bureau.
Per Capita Income $(PCAPI_{it})$	Annual State Per capita income (millions of Dollars)	US Bureau of Economic Analysis (BEA).
Gasoline Price $(GASP_{it})$	Annual Average gasoline price (dollars) per gallon in each state for a period.	Federal Highway Administration (FHA)
Temperature $(TEMPV_{it})$	Sample Variance of Annual temperature	National Centers for Environmental Information (NCEI)

[i] EV (Electric Vehicles) include Battery EV (BEV) and Plug-in-hybrid EV (PHEV) light-duty vehicles.
[ii] Light Duty Vehicles include passenger cars, light trucks, vans, and sport utility vehicles with a gross vehicle weight rating (GVWR) of less than 8,500 pounds (FHA, 2021).
[iii] For electric, the total includes charging ports rather than station locations (AFDC).

Data: Summary Statistics

Table 1: Summary Statistics

VARIABLES	Obs.	Unit of Measurement	Mean	STD	Min	Max	Geographical Unit
Gas Price	510	Dollar per gallon	3.86	5.272	15.37	46.14	State
Per Capita Income	510	Millions ($)	52,465	10,705	33,976	97,498	State
EV Share	510	Percentage (%)	0.00188	0.00301	1.15e-06	0.0257	State
Temperature Variance	510	Fahrenheit (°F)	0.313	0.362	0.00811	2.547	State
Gasoline Consumption Per Pop	510	Mil. of Gallons/Pop	1.378	1.454	0.0952	12.43	State
EV Chargers Per 10k Pop	510	Count/10k Pop	0.463	0.499	0	3.346	State

source: Author's Construction, 2025

Empirical Models and Estimation Techniques

EV Share Equation

$$EVshare_{it} = \ln\left(\frac{EVshare_{it}}{1 - EVshare_{it}}\right) = a_i + \gamma_t + \beta_1 INFRS_{it} + \beta_2 PCAPI_{it} + \beta_3 TEMPV_{it} + \beta_4 GASP_{it} + v_{it} \ldots\ldots\ldots\ldots \quad (2)$$

Emission Equation

$$Em_{it} = a_i + \gamma_t + \beta_1 INFRS_{it} + \beta_2 PCAPI_{it} + \beta_3 TEMPV_{it} + \beta_4 GASP_{it\,it} + v_{it} \ldots . (3)$$

Estimation Techniques

Fixed Effect

Random Effect

Results

- Infrastructure Enhances EV Adoption in the United States.
- Adding one extra charging infrastructure per thousand population is associated with a 0.4% increase in EV adoption.

Table 2: Effects of EV Charging Infrastructure on EV Adoption

Dependent Variable	**Log (EV-Share)**		
	OLS	FE	RE
Infrastructure	0.0035***	0.0040***	0.0039***
	(0.0005)	(0.0011)	(0.0011)
Temperature Variance	-0.0004**	0.0003*	0.0001
	(0.0002)	(0.0001)	(0.0001)
Log(Per Capita Income)	0.0020***	0.0038*	0.0029
	(0.0007)	(0.0022)	(0.0019)
Log(Gas Price)	0.0038***	0.0033***	0.0034***
	(0.0006)	(0.0005)	(0.0005)
Constant	-0.0336***	-0.0515**	-0.0419**
	(0.0080)	(0.0236)	(0.0209)
Observations	510	510	510
R-squared	0.6209	0.6500	0.6484
Time trend		Yes	Yes

Notes: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Results Contd

- Infrastructure has no significant effect on Emission in the United States.

Table 3: Effects of EV Charging Infrastructure on Emission

Dependent Variable	**Emissions: Log (Gasoline Consumption/Population)**		
	OLS	FE	RE
Infrastructure	-0.0552	0.0175	0.0195
	(0.0394)	(0.0404)	(0.0387)
Temperature Variance	-0.1424***	-0.0408*	-0.0441**
	(0.0493)	(0.0221)	(0.0224)
Log (Per Capita Income)	-0.8117***	-0.2388	-0.2667*
	(0.1341)	(0.1455)	(0.1442)
Log (Gasoline Price)	0.0783	0.0376	0.0387
	(0.0888)	(0.0389)	(0.0392)
Constant	8.8004***	2.6485	2.9477*
	(1.4271)	(1.6598)	(1.6358)
Observations	510	510	510
R-squared	0.1588	0.1426	0.1434
Time trend		Yes	Yes

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Results Contd

- OLS shows infrastructure has significant effect on Emission in the West.
- FE and RE shows inverses but insignificant relationship between Infrastructure and Emission in the West.

Table 4: Effects of EV Charging Infrastructure on Emission In The Western Region

Dependent Variable	**Emissions: Log (Gasoline Consumption/Population)**		
	OLS	FE	RE
Infrastructure	-0.3256***	-0.0256	-0.0262
	(0.0952)	(0.0501)	(0.0496)
Temperature Variance	-0.2956**	-0.0917***	-0.0919***
	(0.1280)	(0.0215)	(0.0215)
Log (Per Capita Income)	-0.2242	-0.0495	-0.0493
	(0.3859)	(0.1479)	(0.1480)
Log (Gasoline Price)	-0.1652	0.0639**	0.0635**
	(0.2586)	(0.0281)	(0.0280)
Constant	3.5438	0.6753	0.6739
	(4.1412)	(1.5516)	(1.6909)
Observations	130	130	130
R-squared	0.1205	0.1797	
Time trend		Yes	Yes

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Key Finding 1: Charging Infrastructure Enhances EV Adoption

- **The results show that infrastructure enhances EV adoption.**
- Charging Ports: Adding one extra charging port per thousand population is associated with a 0.4% increase in EV adoption.
- Charging Stations: **While an additional charging station corresponds to a 2% increase.**
- Private charging stations are more strongly associated with EV adoption than public stations.
  - Adding one more **private charging station** per thousand population is associated with a **15.7%** rise in EV adoption.
  - Compared to a **2.8%** increase linked to **public charging stations.**

Key Finding 2: No Significant Effect of Aggregated Charging Infrastructure on Emissions.

Overall, the aggregated effect of all charging infrastructure types on emissions is statistically insignificant.

- However, emissions outcomes differ by infrastructure type as public stations are associated with reductions in transportation emissions.
- While private stations appear to be linked with modest increases.

Policy Recommendations

- Given the stronger association between private infrastructure and EV adoption, state and federal policymakers should prioritize private charging investments.
- Investment in public EV charging infrastructure should focus on equitable access, prioritizing under served communities and high-traffic corridors.
- To fully realize the environmental benefits of EVs, charging infrastructure must be powered by clean energy. We recommend promoting the integration of renewable energy, such as solar and wind—into charging systems.

Feedback: Questions, Comments, and Suggestions

Thank You!

- **Questions?**
- **Comments**
- **Suggestions**