Driving Change: State Policies Affecting EV Adoption

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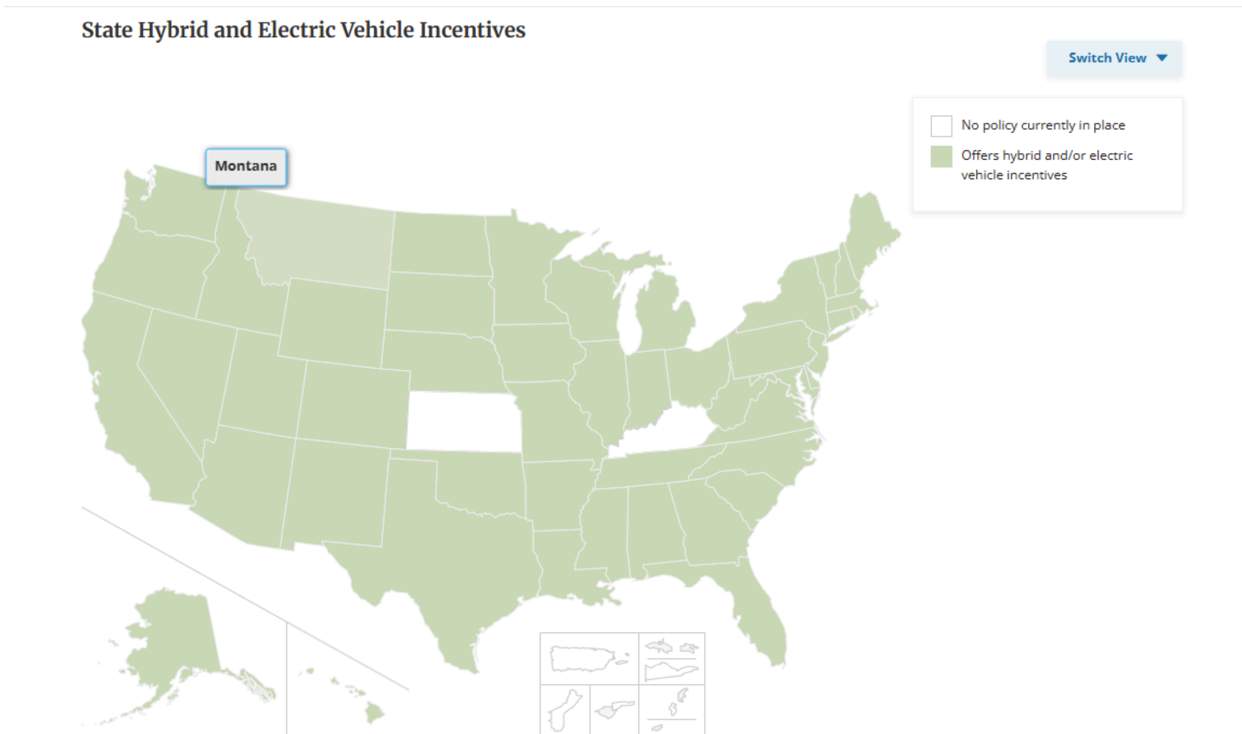
Introduction

With global emphasis on environmental policies and sustainable projects, the world has seen a transition to more eco-friendly products. With emphasis on low carbon products and sustainable transportation methods, Electric Vehicles (EVs) have emerged as a great substitute for fuel-powered vehicles, reducing carbon emissions and transitioning to a more sustainable transportation method. Over the past decade and a half, EV adoption has increased significantly which has been driven by advancement in battery technology and consumer awareness of environmental concerns.

Transportation here in the US is the largest source of greenhouse gas emissions, amounting to around 29% of national emissions. To counter this, here in the United States, electric vehicles have been adopted at an increasing rate. A study shows that EV sales in the US rose from 1.2% in 2017 to around 8% in 2022 (climateadoptionplatform.com). Another study shows that around 4.09 million electric vehicles are driven in the US (edmunds.com). However, electric vehicles adoption rate across states varies greatly as some states have openly welcomed this change while other states are reluctant to make the technological change as shown in Fig 1 below. The variation in the adoption rates raises questions on the factors responsible for EV adoption, especially state level policies.

Fig 1: EV Incentives across the US



In this paper, we aim to navigate the various factors that influence adoption rates of EVs while conducting a comparative analysis between two neighboring states, Colorado and Kansas. Through our comparative analysis, we intend to look at factors that drive EV adoption such as incentives which include tax cuts and rebates, charging stations, income levels etc. Our reasoning for choosing these two states is to assess the impact of state policies on EV adoption rates as Colorado has robust policies encouraging EV adoption whereas Kansas has implemented lesser policies and consequently seen a lower EV adoption rate. Understanding the causes and effects of policies can be instrumental in crafting policies to promote sustainable transportation methods across the country.

Literature Review

The adoption of electric vehicles has been a hot topic across the US and the globe as well, hence numerous studies have been done to understand the factors that influence adoption rates. Two of those studies have been used as an inspiration to write this paper.

The first paper that we are going to look at is - *"The Impact of State Policies on Electric Vehicle Adoption - A Panel Data Analysis (2024)"* - by Maher F. Mekky and Alan R. Collins was published in the journal *Renewable and Sustainable Energy Reviews Vol 191* . This paper compares three metrics: Environmental Policies, Financial State Incentives and Infrastructural Support. Two of these metrics are used in our paper; hence laying the foundation for our thesis below.

The authors used data from all 50 U.S. states between 2012 and 2020. They focused on three types of policies: environmental policies, financial incentives, and charging infrastructure. We found that environmental policies had the biggest impact. For example, states that used more clean energy or produced less CO_2 had more EVs. A small increase in clean energy use or a drop in CO_2 emissions led to a noticeable rise in EV adoption.

We also saw that financial incentives matter. But not all types worked the same. Tax credits had a strong effect, while rebates did not help much. This means that how the money is given to people matters. Tax credits seem to work better. This connects to our research because we are also thinking about income and how people respond to different types of support when buying EVs.

Charging stations also had a positive effect, but it was smaller than the effect of environmental policies. People are more likely to buy EVs in states with strong climate policies and easy access to clean energy.

This study helped us understand that state policies really do matter. States that care more about clean energy and offer clear financial support have higher EV adoption. We plan to use these ideas to guide our own research.

The second paper that was used for this paper was - “Impact of Financial Incentives on Battery Electric Vehicle Adoption” - by Bentley C. Clinton and Daniel C. Steinberg (2019), published in the Journal of Environmental and Economics Management. This study helped us understand how financial incentives from the government can affect the number of people buying electric vehicles (EVs), especially battery electric vehicles (BEVs).

The authors used data from U.S. states between 2010 and 2015. They tested how state programs like tax credits and rebates impact how many people buy EVs. We found that financial help does make a difference. But small amounts of money don’t help much. Bigger incentives, like over $5,000 have worked better.

We also learned that when the money is given matters. People like it more when the money is taken off the price right away (point-of-sale) instead of waiting for a tax return. This is important for our research because we are looking at how people’s income and gas prices affect EV adoption. If people have less money, they may need help right away.

The study also looked at other things like charging stations and gas prices. Even with these factors, money incentives still helped a lot. That shows us that state policy is very important.

This paper helped us think about our own research. It showed us that strong and simple incentives can really help more people switch to EVs.

Data Collection

For this paper, multiple sources were used to collect the data and use the proceeding results to understand the factors that influence EV adoption rates between the two states.

To estimate EV adoption rates, we used data from the U.S. Department of Energy's Alternative Fuels Data Center. We calculated the adoption rate by dividing the number of registered EVs by the total number of registered vehicles for each state and year. This allowed us to track how EV usage is growing over time.

For economic indicators, we looked at median household income. We used data from the Kansas State Data Center (IPSR) and the Federal Reserve Bank of St. Louis (FRED) to find state-level income levels. These helped us analyze how income might influence the ability to afford EVs.

Gasoline prices were collected from the U.S. Energy Information Administration (EIA). We used monthly retail gasoline price data (in dollars per gallon) as a possible factor in consumer decisions to switch to electric vehicles.

Lastly, we used the Alternative Fuels Data Center again to find the number of EV charging ports in each state. This variable helps measure the availability of charging infrastructure, which is important for EV convenience and adoption.

Together, these datasets allowed us to create a panel for analyzing the relationship between EV adoption and factors like income, gas prices, and infrastructure.

Empirical Model

For this paper, to provide an accurate evidence as to whether state policies affect EV adoption rates, we will run a simple linear regression model which is as follows:

$$EVAdoption = \boldsymbol{\beta 0} + \boldsymbol{\beta 1} EVIncentive + \varepsilon$$

For this model, we have created a dummy binary variable, EVIncentives. 1 represents Colorado which has robust EV incentives while 0 represents Kansas which has no incentives. Through this model, we are only evaluating the effect of state policies on EV adoption rates while holding other variables indifferent.

Moving further, to understand, if there is a casual relationship between state policies and EV adoption rates, we will run a multiple linear regression model which includes other variables other than state incentives which are infrastructure promoting EV adoption which includes charging stations for EVs, average gas price throughout the years and median income levels in both the states which can be seen in the following model:

$$EVAdoption = \boldsymbol{\beta 0} + \boldsymbol{\beta 1} EVIncentive + \boldsymbol{\beta 2} CharginPorts + \boldsymbol{\beta 3} Gas\_Price + \boldsymbol{\beta 4} Median\_Income + \varepsilon$$

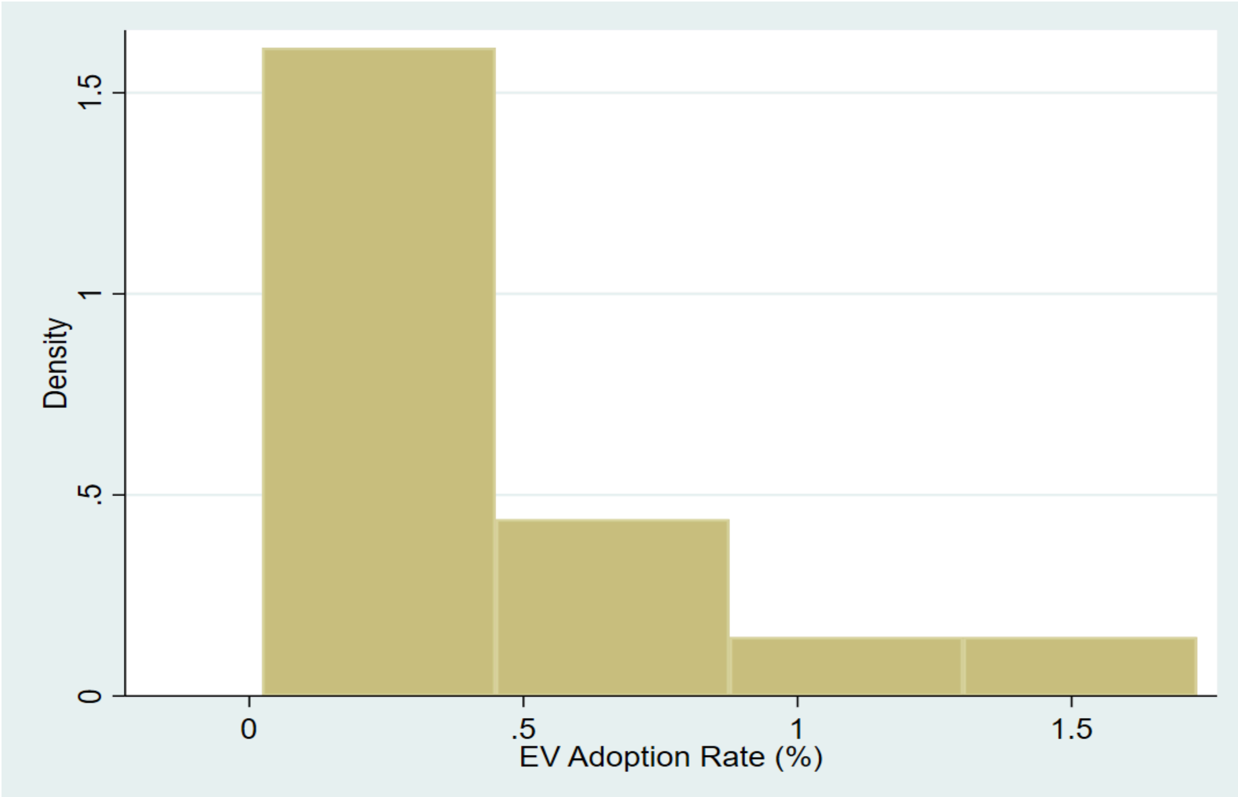
This model will help better analyze which variable plays the biggest role in EV adoption and would help us determine if state incentives are the largest determinant of driving EV sales.

Fig 2: Table Showing Variables and Expected Relationship for the Regression Model

Coefficient	Independent Variable	Expected Relationship
β1	EVIncentive	Positive
β2	ChargingPorts	Positive
β3	Gas_Price	Positive
β4	Median_Income	Positive

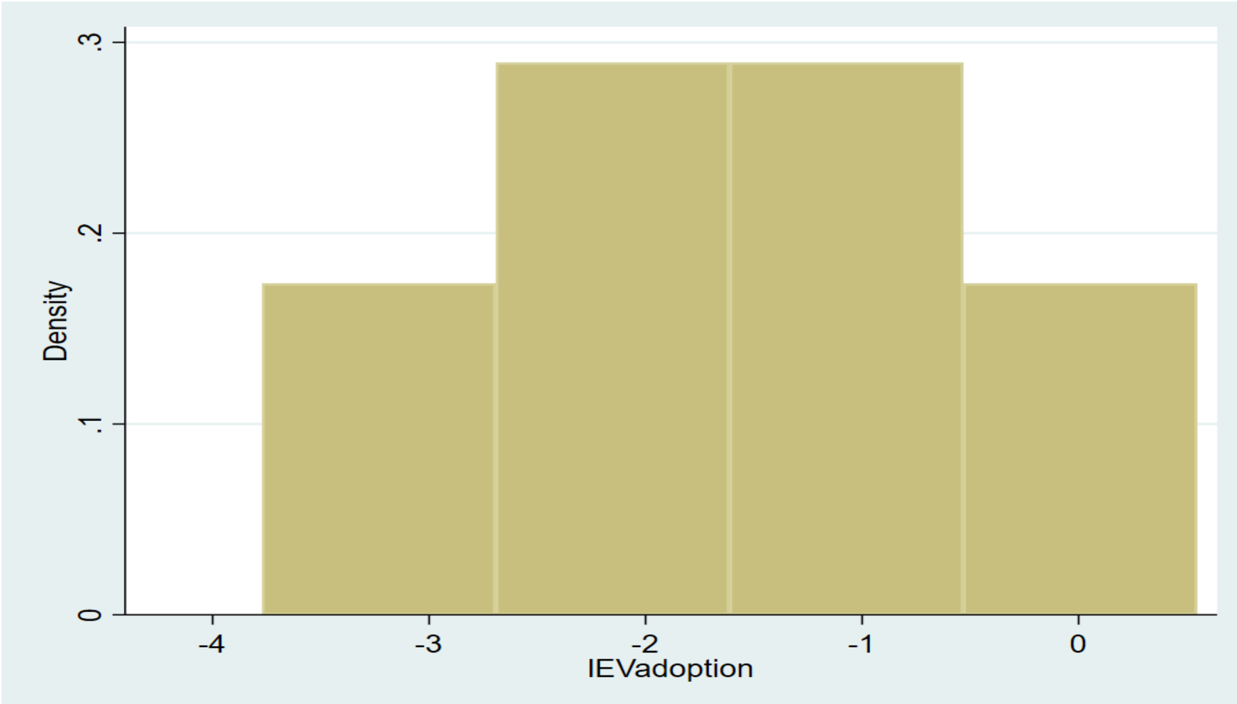
To provide accurate results, the first regression model was run and while it did provide the expected result, running the second regression model produced unreliable results i.e. there was a negative relationship between the EV adoption rate and EV incentives. Dissecting into the data and making a histogram provided insights as to why there was this negative relationship.

Fig 3: Histogram showing the EVAdoption dependent variable with skewed data



As can be seen in the figure above, it shows that the data was highly skewed to the right indicating the asymmetric nature of it. Skewed data violates the assumption that the data between the observed and predicted values is normally distributed and can lead to biased standard errors and coefficients. It can also lead to heteroscedasticity, where the variance of the residuals is not constant across the range of predictor variables, affecting the accuracy of the findings. To counter this problem and proceed with the regression model, we generate a new variable by logging our dependent variable (EVAdoption). The new variable i.e lEVAdoption results in the data being less skewed (as shown in Fig 4) and produced accurate results. Logging the dependent variable was essential for this regression model to yield results that were accurate and addressed homoscedasticity and linearized the relationship between the variables.

Fig 4: Histogram showing the lEVAdoption Dependent Variable



Regression Analysis

Fig 5: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
levadoption	16	-6.215	1.246	-8.393	-4.058
EVAdoptionRate	16	.385	.469	.023	1.729
EVIncentive0or1	16	.5	.516	0	1
ChargingPorts	16	1995.125	1633.43	725	6185
Gas Price	16	2.561	.936	1.143	4.342
Median Income	16	82198.063	9046.163	67090	96640

The table above shows the statistical summary of the data set used. It includes the mean, standard deviation and range of the data set. Looking at the figure, we see that the average EVAdoptionRate is .385 while levadoption has a mean of -6.215 which is not an abnormal figure as log generated variables can have a negative mean. The average of EVincentive is 0.5 which is expected as this is a binary variable. Infrastructural policies show the presence of more charging ports with an average of 1996 ports across the two states. The average gas price in the two states was $2.561 while the average household income was $82,198.06. Both these variables are also important in determining EV adoption.

The first regression model that was run took into account the linear regression model where the only variable that was being analyzed was the EV incentive. The results of the regression had the expected outcome as it showed that there was a positive correlation between the EV adoption rate and the EV incentives.

Fig 6: Table formulated with single variable.

	(1)
VARIABLES	lEvadoption
EVIncentive0or1	1.462**
	(0.513)
Constant	-6.946***
	(0.378)

Observations	16
R-squared	0.368

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Looking at the results of this regression, since the start of the time period analyzed, there has been an increase in EV adoption rate when there were EV incentives. Colorado, which has robust EV incentives sees more EVs adopted when compared to Kansas which has little to no incentives. The **β**1 value came out to be 1.462 which shows that incentives lead to a 146.2% increase in new EV sales keeping everything else equal.

This is a statistically and practically significant result and as the p-value($0.013<0.05$) shows that the model is statistically significant at the 5% significance level. With this, we can say with 95% confidence that incentives lead to a higher adoption rate. The R-squared value of 0.368 shows a 36.8% variation in the EV adoption rates across the sample is explained whether the incentive is available or not. This explains that although incentives are important, it cannot be attributed as the single most important variable that contributes to EV adoption.

To account for other variables that influence the EV sales, we ran our MLR to get a better overview of these variables. The results are as follows:

Fig 7: Table formulated with multiple variables

	(1)
VARIABLES	lEvadoption
EVIncentive0or1	0.921**
	(0.405)
ChargingPorts	0.000257***
	(6.76e-05)
Gas_Price	0.720***
	(0.154)
Median_Income	5.40e-05***
	(1.72e-05)
Constant	-13.47***
	(1.706)
Observations	16
R-squared	0.906

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The presence of EV incentives in Colorado is statistically significant with the resulting p-value of 0.042 ($p<0.05$). The expected positive coefficient of 0.921 shows a positive relationship between the presence of EV incentives and lEVadoption. This shows that the presence of EV incentives in Colorado leads to a 92.1% increase in EV adoption rates when compared to Kansas where there are no EV incentives showing the significance of the presence of EV incentives.

The second variable that is taken account for is the charging ports. This is an infrastructural policy that drives EV sales and the p value of 0.00 shows that it is highly significant in driving EV sales. The coefficient here shows a positive correlation implying that the presence of an additional charging port is, on average, likely to drive EV sales by about 0.0257%.

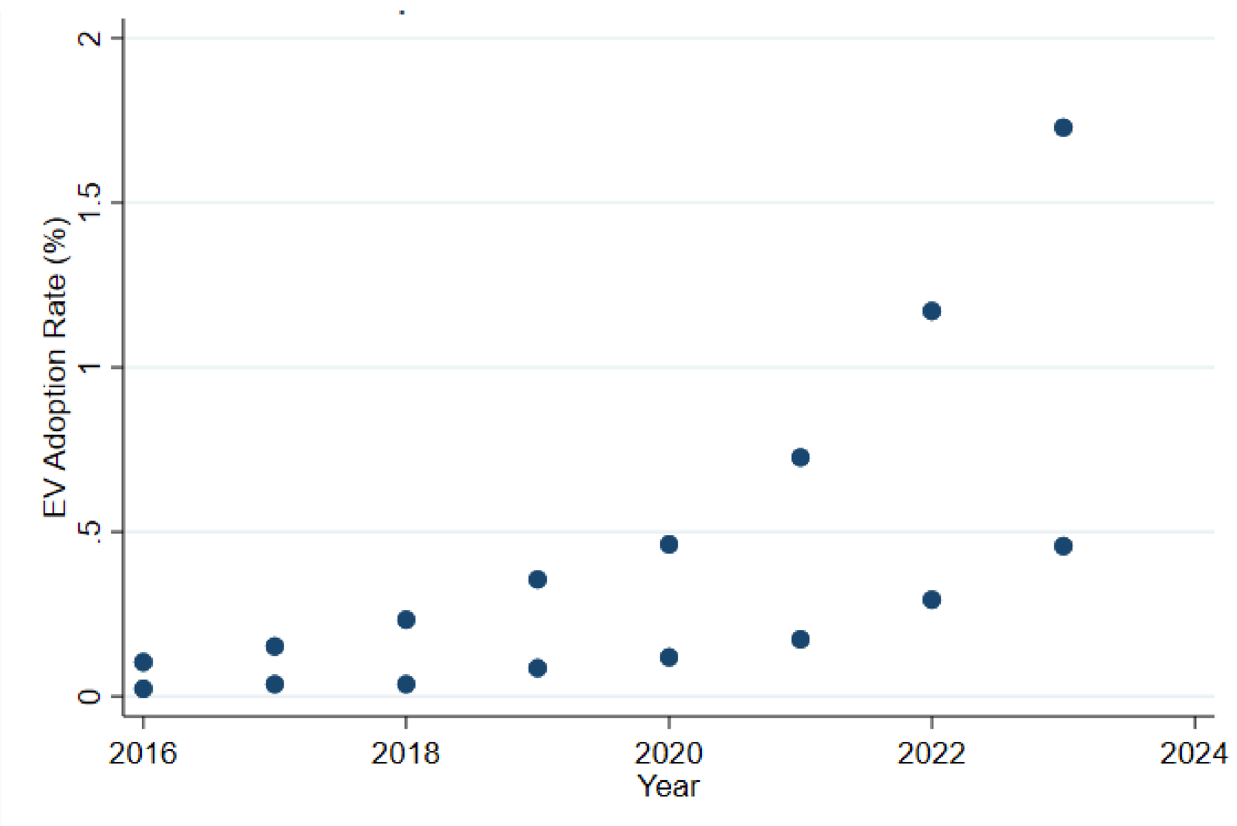
The next variable that we have regressed is the average gas price in each state. Since gas is used in fuel-powered vehicles which are substitutes to electric vehicles, an increase in gas prices is likely to result in consumers switching to electric vehicles. This relationship is highly statistically significant with a p-value of 0.001 shown by the coefficient of gas prices which is 0.720 showing that an increase in $1 of gas prices would increase EV sales by 72%.

The last variable that we are going to analyze is the median income of households in each state. The more the income present in a household, the higher their purchasing power and hence it can be inferred that higher income would result in higher EV sales. Median income is statistically significant with a p- value of 0.009 and its coefficient shows for every $1 increase in income leads to 0.0054%.

The regression results here show that both financial and infrastructure variables play a key role in EV adoption. The presence of charging ports driving EV adoption highlights the importance of EV adoption. Higher gas prices result in people switching away from fuel powered vehicles as a means of cost saving. Areas with higher median household income show higher rates of EV adoption. The R-squared value of 0.906 shows a 90.6% variation in the EV adoption rates across the sampe are attributed to these statistically significant variables.

To further see the results of EV adoption rates across the two states, a scatter plot is used to illustrate the EV sales across the two states over the time period analyzed. Looking at the scatter plot in Fig 8, it can be inferred that there was an increase in EV sales especially in Colorado when compared to Kansas considering an increase in the variables analyzed above showing significant results.

Fig 8: Scatter plot showing EV Adoption: Colorado vs Kansas



Limitations

While drafting this paper, we encountered several limitations specifically related to the gathering of data.

The first problem that we encountered was the availability of the data that was to be analyzed. Since EVs are a new topic across the globe and specifically here in the US too, which has risen within the past decade and a half, there was limited data available for the analysis. The reason for this is because, since it is a relatively new concept, initially it was not being monitored and authorities only started monitoring data related to EVs from 2016. Because of this, for our paper, we only had 9 years of data and since we are comparing two states, we only had 18 observations.

The second problem we encountered was that of determining which states to analyze. EV adoption rates vary across the country, some states have higher adoption rates and while some have fewer. To determine accurate results, our primary focus was to analyze two neighboring states, where one has robust EV incentives and the other state has little to no incentives.

Another limitation that we encountered was trying to establish the causal relationship between presence of EV incentives and Ev adoption. The presence of other variables such as gas prices, charging ports do play a role in EV sales and go side by side with EV incentives. As shown by the regression results, other variables are also statistically significant, hence it was not possible to establish a causal relationship.

Conclusion

To conclude this paper, it can be concluded that even though state level incentives are not the main factor driving EV adoption, they play a significant role in the adoption of EVs across the US. Through a comparative analysis of two neighboring states with different EV policies, the findings of this study reveal that EV incentives positively and significantly affect EV adoption. The exponential growth of EV sales in Colorado in comparison to Kansas can be attributed to the presence of state incentives as can be seen in Fig 8. The figure also shows that EV sales skyrocketed post-covid from 37000 in 2021 to 59900 in 2022 to 90100 in 2023.

While state incentives alone do not influence EV adoption, they play an important role when combined with other variables. Our regression model also accounts for variables such as charging ports, gas prices and median income with an R-squared value of 0.906 implying that these variables account for 90.6% of the variation in EV adoption across the sample. The availability of charging ports and gas prices are strong drivers for EV adoption highlighting the importance of both economic and infrastructural policies driving EV adoption.

However, this paper highlights certain limitations such as a small data set and difficulty in establishing a causal relationship between incentives and EV adoption. Keeping these limitations under consideration, we still conclude after a thorough analysis that state level incentives have a positive and significant impact on EV adoption.

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