Determining contributing factors for Electric Vehicle Adoption

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1 Objective

Identify factors influencing the adoption of electric vehicles and analyzing the effect of such factors based on past decade's history.

- Determine the major factors impacting the adoption of electric vehicles.

- Anaylze the patterns from historical data to define correlation.

2 Introduction

Transportation industries are essential in the present world and assume a play an imperative role in any country's development. With financial advancement and upgrades in expectations for everyday comforts, the issues caused by transportation, for example, unreasonable oil utilization, air contamination, and ozone-harming substance discharges, will turn out to worsen the situation going forward. To mitigate these issues, the advancement of eco-friendly and option fuel vehicles, specifically, electric vehicles (EVs), has turned out to be one of the fundamental points in the automobile business in numerous nations. Electric Vehicle Adoption is influenced by a lot of factors. The parameters which contribute to the adoption of electric vehicles include demographic characteristics, the existing infrastructure to support or promote use of Electric Vehicles and administrative policies among other influencers. Specifically, we analyze it based on the weighted value of key attributes including demographic factors, costs, incentives, infrastructure etc. The average importance of several attributes changes nonlinearly across its range and changes with income. We identify such key attributes and present a correlation on how they affect electric vehicles adoption. We feed data for such key factors to a LightGBM model (gradient boosting framework that uses tree based learning algorithm) to get weights for the factors. Output weights will give us a correlation between the key factors by how much they are contributing to EV adoption.

3 Domain Survey

In order to get an idea about how to best approach the problem, we started by exploring previous literature that might have worked on the similar quest. We came across some great research papers which have had objectives that made them study these factors for one purpose or another.One great report came from [1] where the authors studied the effects of state and local incentives on EV adoption. They recorded and tested their hypothesis on multiple kinds of incentives offerd by different states in varying degree and concluded that while these incentives are important, they are not sufficient to draw a strong estimation or correlation with EV adoption. Another study by U.S. Department of energy[2] explored the contribution of suitable infrastructure in EV adoption rate along with a couple of demographic variables. They observe that increasing charging station density by one per 100,000 drivers corresponds to a 3.2% increase in plug-in EV purchases.Improved access to charging infrastructure reduces range anxiety.Demographic characteristics—particularly,age, income, and educational attainment—are also correlated with EV purchases.
Also, we extensively gleaned the government and other credible websites that promised to provide trustworthy statistics in this domain.

Some very insightful resources were found at a couple of places like:

- **National Renewable Energy Laboratory (NREL)** Great place to delve into the latest reports and studies on the renewable energy application and resources.

- **US Department of Energy** The official US government site where they keep up to date statistics and data about all possible aspects and forms of energy.

- **Alternative Fuel Data Centre (ADFC)** Basically a subsection of energy department site that deals exclusively with the alternate fuel and stats about any application and influencing factors for it.

- **US Census** The source of archived data about demographic and socioeconomic factors.

- **Auto Alliance** This website collectes data about any kind of automobile sale records and trends. We picked our EV adoption/registration statistics from here.

4 Major Factors Explored

4.1 Demographic Factors

- **Mean Household Income**

    Household income depicts the economic trends of the location. The median household income would give a better estimation of economic status of the state. Since the electric vehicle adoption requires an investment cost at the start, this factor has a significant influence.

State Name	2012	2013	2014	2015	2016
California	85265	85408	86704	87877	91149
Florida	66599	66368	67143	67975	69936
Minnesota	76372	77204	79106	80444	83100
Arizona	67444	66971	67557	68297	70432
Montana	59569	60639	62086	63139	65401
Kansas	67564	68051	69271	70093	71975

Figure 1: Mean House Hold Income for selected US states

- **Median Age**

    This divides the population into two equal groups based on age. Median age index is used to summarize the age distribution of a population effectively.

- **Educational Attainment**

    Educational attainment is the highest level of education attained by an individual. We considered the people who have completed atleast a Bachelor's degree.

State Name	2012	2013	2014	2015	2016
California	7656950	7795640	8158064	8415690	8660470
Florida	3439430	3530070	3620940	3780148	3929796
Arizona	1103888	1132811	1161170	1199010	1241425
Minnesota	1138849	1161319	1194943	1225245	1253937
Montana	191331	193892	198348	203448	209072
Kansas	551423	558703	571601	580214	593801

Figure 2: Educational Attainment for selected US states

4.2 Costs

- **One-time costs: Vehicle, Battery, Unit installations**

- **Recurring costs: Maintenance, Insurance**

- **Gasoline prices**

    Adoption of Electric vehicles includes one time investment costs as well as recurring costs, which would significantly affect the adoption rate. Gasoline prices also keep varying, which has an effect on the adoption rate.

State Name	2012	2013	2014	2015	2016
California	4.081	3.933	3.794	3.221	2.782
Florida	3.629	3.572	3.421	2.438	2.216
Minnesota	3.562	3.496	3.296	2.398	2.09

Figure 3: Gasoline price changes for the selected US states

4.3 Incentives

- **Purchase/Tax/Registration Rebates**

- **Parking Exemption**

- **HOV (High Occupancy Vehicle) Lane Exemption**

- **Supply Equipment Exemption**

  There are multiple aids, exemptions and special fecilities provided by local and state governments acorss US for people who choose to move to alternate fuel vehicles. This includes government policies on monetary endowments, tax reductions, registration rebates, parking and lane exemptions, driving privileges etc.. Every one of these strategies are employed to encourage the adoption of EVs. These impacts were found to increment when more ground-breaking policies are issued. From a financial viewpoint, embracing EVs by people is correlated with the monetary motivating forces of current policies, which can enable people to save money. The amount of these financial incentives again vary with the enforcing governments and while some areas provide quite a good number of incentives on EV adoption, there are other factors(mostly demographic) which hinder the rate of anticipated adoption.

State	Registrations	HOV Lane Exemption	Purchase Rebate	Tax Credit	Parking Exemption	Registration Fee Rebate	Charging Rate Incentive	Supply Incentive
California	145256	1	1	0	1	0	1	1
Florida	25471	1	1	0	0	0	0	1
Texas	21615	0	1	0	0	0	1	1
New York	21296	1	1	1	0	0	1	1
Michigan	18740	0	0	1	0	0	1	0
Washington	15683	0	0	1	0	0	1	1
Illinois	14913	0	0	1	0	0	0	0
Virginia	13292	1	1	1	0	0	0	0
North Carolina	12541	1	1	1	0	1	1	0

Figure 4: Example of Incentive Distribution across selected US states

4.4 Infrastructure

- **Charging Stations**

  The long charging time and lacking charging stations is viewed as another specialized boundary. If the charging time can be lessened and charging foundations can be easily accesible, their negative effect cannot be overlooked. Given that reduing the charging time is difficult to acheive currently, we can focus on charging stations. Charging availability at work place and the number of charging stations in the general population space are vital. Charging stations should be made available in general society area like grocery stores, parks, eateries etc.. enhance EV adoption rate.

State Name	2018
California	5429
Florida	1258
Minnesota	315
Arizona	476
Montana	40
Kansas	198

Figure 5: Charging station count for Year 2018

5 Results and Inferences

5.1 Educational Attainment

The correlation of educational attainment and the electric vehicle adoption differs from state to state. For example, California saw an increase in electric vehicles with the increase in educational attainment unlike Arizona and Minnesota. The educational attainment along with other factors are collectively affecting the adoption rate.
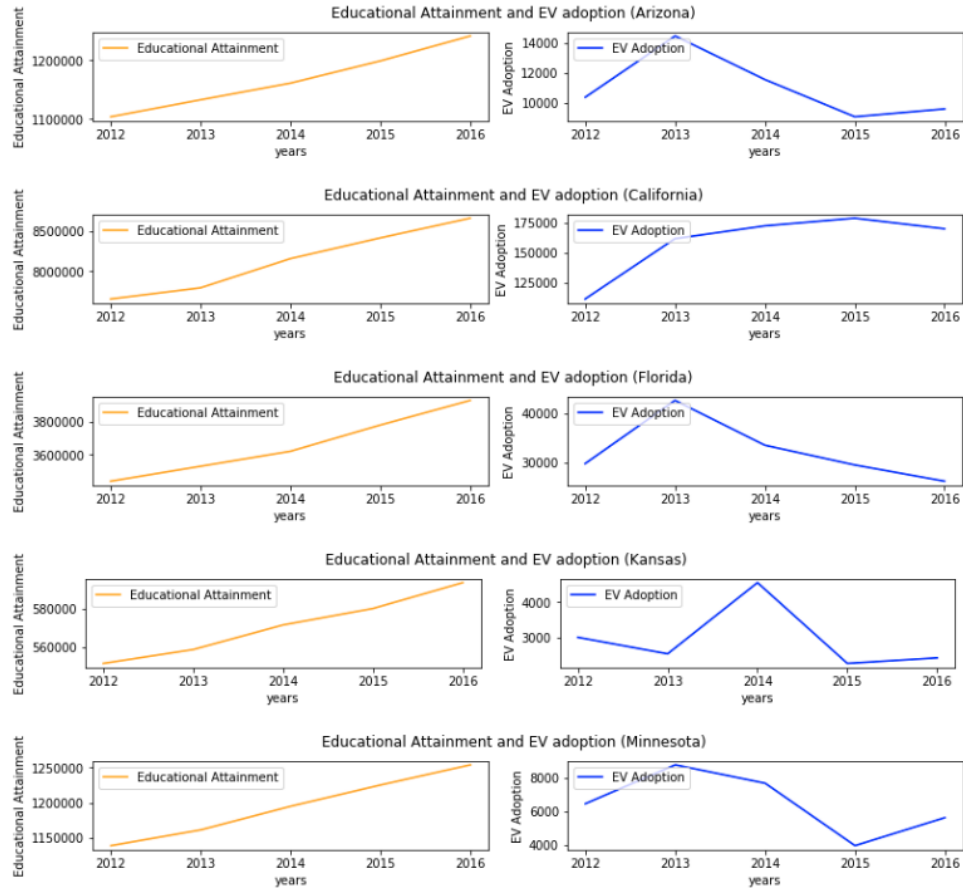

Figure 6: Educational Attainment vs. EV adoption for selected US states

5.2   Charging Stations

According to [2], Charging infrastructure has a positive impact on EV adoption(by 3.2%). We collected stats for charging infrastructure for top 10 states which hold highest registration count in the yer 2018. We visualized the correlation by following graph.
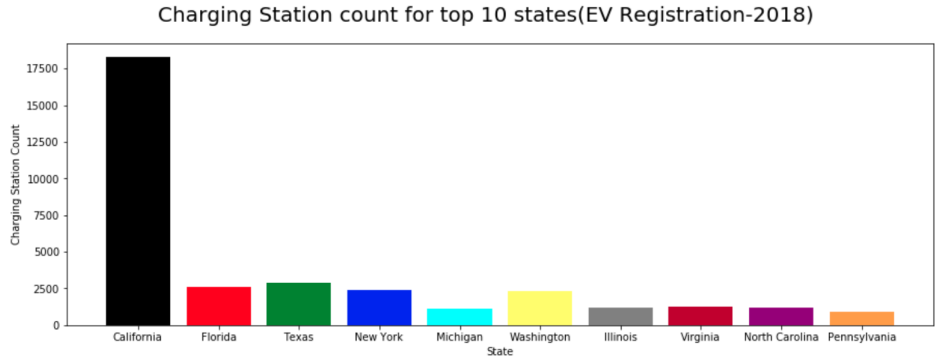

Figure 7: Charging station count for top 10 (EV-registration) states

California has an Unusually high count of charging stations which can be counted as an outliers as is the EV registration count for the state which is probably result of the education attainment rate combined with the area. For the rest 9 states, we can see a positive correlation between charging station count and EV sales.
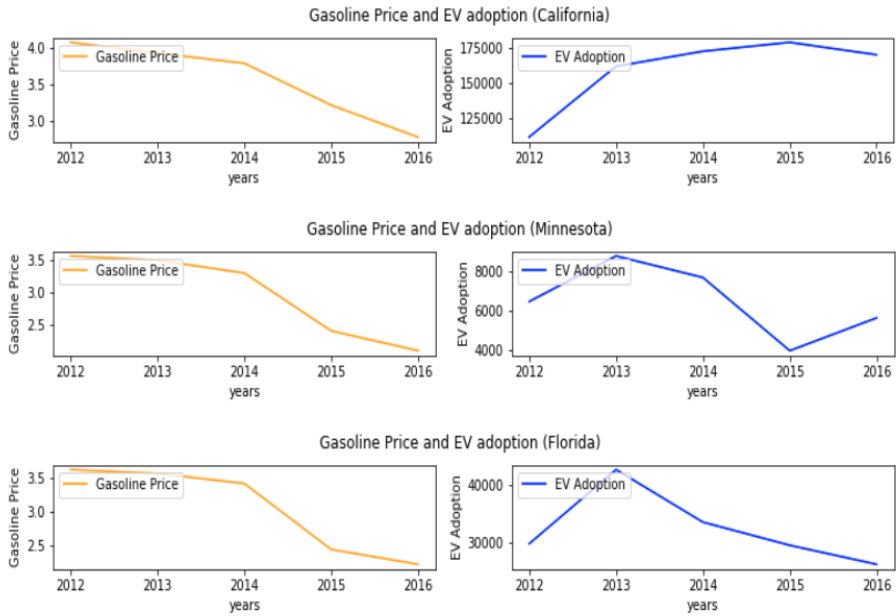
5.3   Gasoline Prices

Figure 8: Gasoline prices vs. EV adoption for selected US states
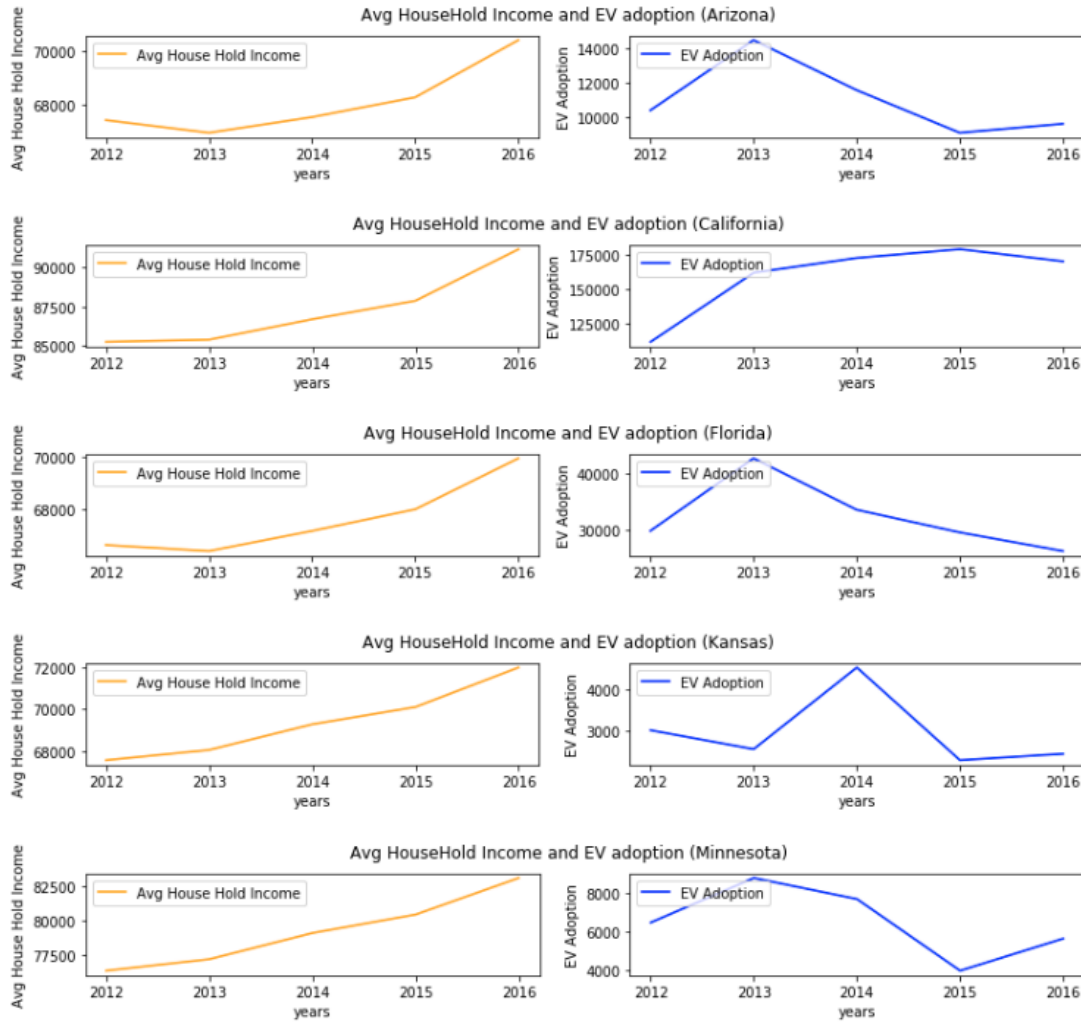
5.4 Average Household Income

Figure 9: Average household income vs. EV adoption for selected US states

Each state differs in the way the household income affected the EV adoption rate. If we categorize the states into median, low, high tier based on income and infrastructure (In Fig. 9 states are considered in this manner), we see a correlation in the plots in high end states and low end states.

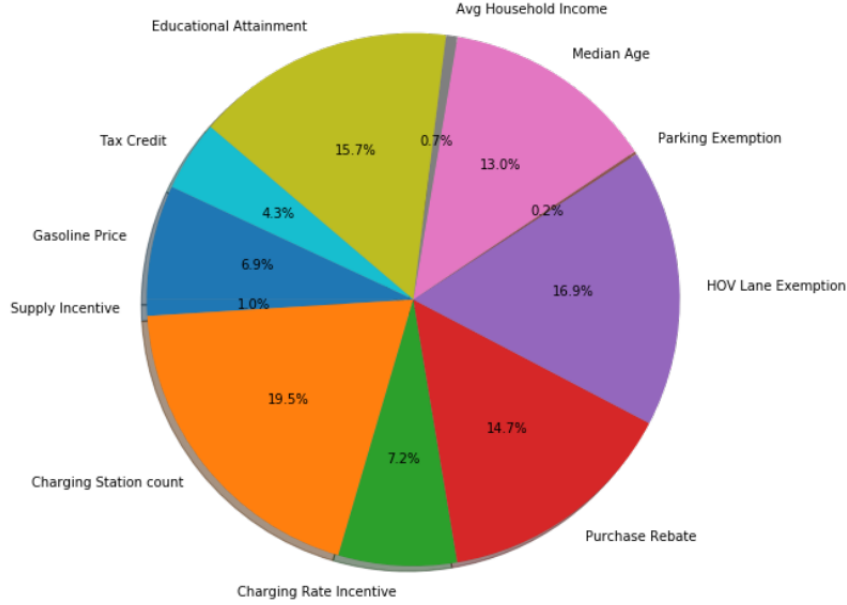## 5.5   Estimating the best contributing factors

Figure 10: Pie chart to show % contribution for each factor

Having more charging stations which is one of the key factor as shown in pie chart facilitates EV adoption. Next best factors are government incentives and rebates. We identified that income is a less prominent factor when compared to age and education. This is because of the reasonable prices of EVs in present day, which is likely a result of the significant market competition.

5.6   Applying Decision Tree for key factors

We collected the above factors for all US states along with their EV registration counts and fed them to a light GBM model which is basically a decision tree regressor. We hoped to see the weights assigned to each factor by the model and determine which factor is deemed more decisive than others. The results are as follows(in descending order of weightage):

1. Charging Station Count

2. HOV lane exemption

3. Educational Attainment

4. Purchase Rebate

5. Median Age

If we divide the states in USA into 3 categories (high, medium, low) based on factors like development, income, infrastructure, we see correlation between factors and EV adoption rate. This looks fair but we strongly believe that this comparison metric cannot be generalized for all the states.

6   Conclusion

During the entire project, we attempted to find the most effective parameter that contributes to the EV adoption rate for US states but we couldn't find a very substantial relationship between a factor and the growth. Some states like California or NY prove to be outliers for any hypothesis. At other places, we find a good growth in EV adoption despite no incentives from the state. So we conclude our study by saying that EV adoption is impacted by a ensemble of variables rather than a single driving force. This conclusion is backed by latest literature available in similar studies.

References

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[3] https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard

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