Analysis and Forecast of Electric Vehicle Sales in the United States with Comparative Studies

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Abstract. This research delves into the dynamic United States electric vehicle (EV) market, marked by a 55% growth in 2022, achieving an 8% sales share. Utilizing Argonne National Laboratory's data, the study focuses on battery electric vehicles (BEVs) and employs ARIMA modeling to analyze 13 years of sales trends. Monthly patterns reveal peaks in the first and fourth quarters, attributed to holiday discounts, new model releases, and tax incentives. The forecast suggests an upward trajectory, estimating 125,000 EV units sold in 2024, with an increase to 150,000 post-2025, hinting at possible market saturation. Acknowledging potential underestimation due to evolving factors like environmental awareness, the research underscores the importance of a holistic approach. Considering consumer perspectives and effective governmental policies is crucial for sustained EV growth and maximizing environmental benefits in this promising frontier.

Keywords: Electric vehicle sales; analysis and forecast; battery electric vehicles.

1. Introduction

This research embarked on a journey into the dynamic world of electric vehicles, where technology, sustainability, and market trends converge to shape the future of transportation in the United States. The US is the third-largest market in the world for electric vehicles, having increased by 55% in 2022, reaching a sales share of 8% [1]. Electric car sales are expected to continue strong growth through 2023. Over 2.3 million electric cars were sold in the first quarter, which is about 25% more than in the same period last year [2].

This research aims to understand how electric cars are growing at such a rapid pace. In this sense, the research delves deep into the electric vehicle landscape, providing a comprehensive analysis of current market dynamics and a forecast that will shed light on the path ahead. This research uses ARIMA modeling to study the data of electric vehicle sales during the past thirteen years in the United States, combined with comparative studies of related social studies, to forecast the possible sales of electric vehicles in the United States in the future.

2. Data Analysis & Model Construction

The data this research used came from Argonne National Laboratory. Argonne National Laboratory is a federally funded research and development center in Lemont, Illinois. Founded in 1946, the laboratory is owned by the United States Department of Energy. The data used is under the “energy system and infrastructure analysis” page.

The data was pre-cleaned. It displays monthly sales, date (from 2010/12 to 2023/8), and the power train. The analysis was mainly focused on battery electric vehicles, therefore the final dataset only contains the BEV column. Here is a simple visualization of the dataset (Figure 1).

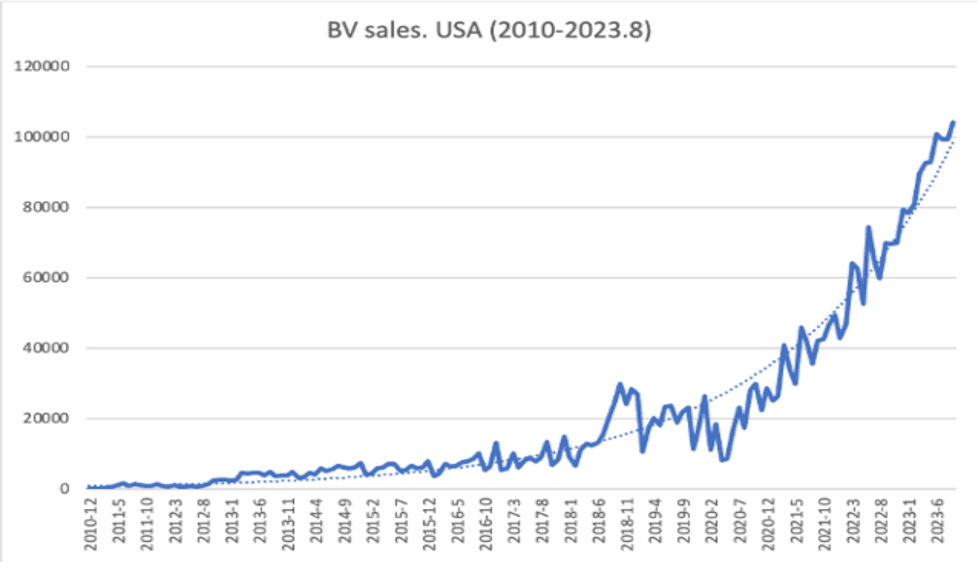

Fig. 1 Battery electric vehicle sales. USA (original)

A rising trend with fluctuations is easily observable. To take a closer look at the fluctuations and see whether it's any seasonality that created this pivot plot which separates each year's sales into a single line.

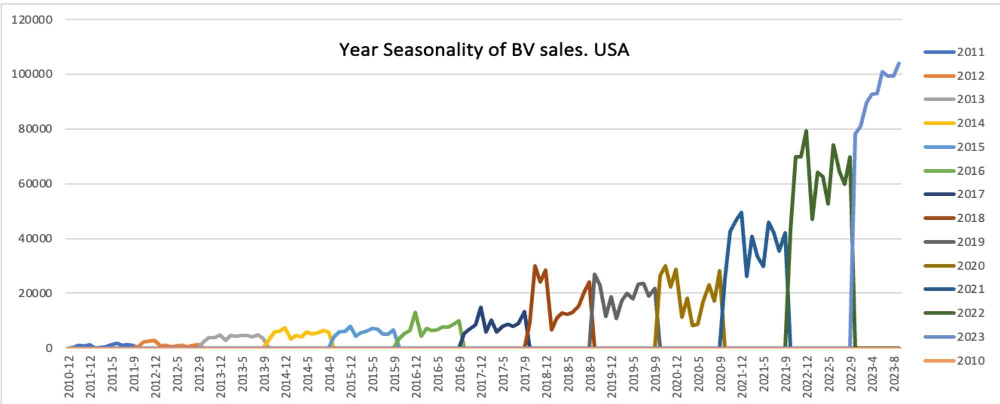

Fig. 2 Monthly sales group by year (original)

According to Figure 2, starting from 2016 most BEV sales were sold in the first and fourth quarters of the year. There are three assumptions. The first is that it has to do with the discount from car dealerships, which happens quite often during Christmas and the New Year holidays. Families tend to make big important purchases during the beginning or end of a year since consumers are always looking for a way to save money on major purchases. The second assumption is which car manufacturers like to introduce new models of vehicles in the fall season of the previous year, like Toyota, Honda, BMW, etc. Therefore during the fourth quarter or the first quarter of the following year, those new models hit the market. The final reason may be because of tax incentives. According to the U.S. Department of Treasury, "Up to $7,500 for buyers of qualified, new clean vehicles. For this credit, there are two lists of qualified vehicles: those purchased in 2023 or later, and those purchased in 2022 or earlier."

Going into R, this research imported and converted the dataset into a time series object, so it becomes perfectly compatible with the "fpp2" package. For forecasting, this research chose the Auto Regressive Moving Average model (ARMA) mainly because of two reasons. First, it has a major advantage over the ETS model in that ARMA models should be able to capture a wider range of time series behaviors, so it also includes those with non-linear behavior. Which ETS models assume linear relationships. Secondly, the dataset contains 155 data points which meets the requirement of the model.

To eliminate the periodic fluctuations and reach stationarity, this research took the log term and differenced the time series. After it was stationary, this research first attempted to manually tune the ARIMA model with the PACF and ACF graphs. The first attempt resulted in extremely low p values which the model did not pass the white noise check. After more attempts and making sure the model was getting the right spike information from the PACF and ACF graphs, the research finally used the auto ARIMA function since it has a guaranteed 98.88% accuracy.

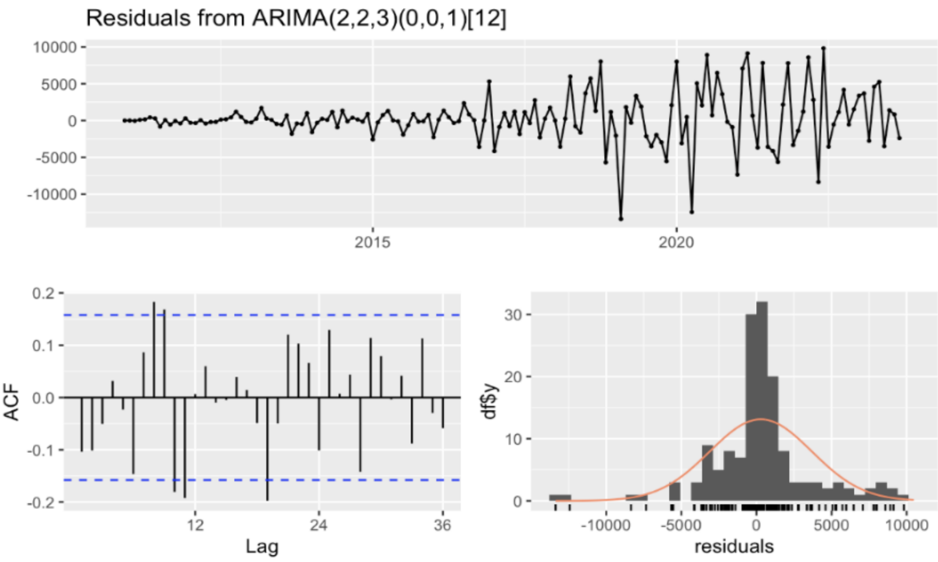

Fig. 3 Default time series with auto ARIMA function applied (original)

As Figure 3 shows, the auto ARIMA function added a seasonal component that was ignored in the first place, however, it has also failed to pass the residual check, with a p-value of 0.0002. From its residual plot, it can observed a huge increase in the error around the year 2017-2018, and it went off after that. As taken with the account of heteroscedasticity because the dependent variable sales have changed significantly from start to end, which explains the error terms. As a result, it proved more efficient to slice the original dataset. The prior years were also removed, and the first data point now starts in 2017/4, which still leaves 75 data points to work with.

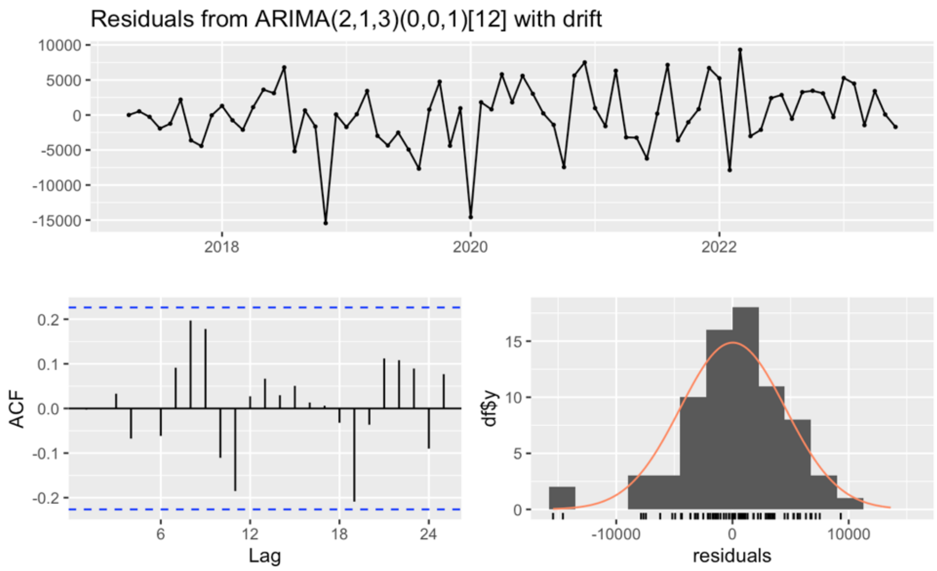

Fig. 4 Sliced time series with auto ARIMA function applied (original)

As Figure 4 shows, with the new time series, the auto ARIMA function successfully passes the residual check, with a p-value of 0.1811. The research also cross-validated with the manual Arima function. It has passed the residual check as well. The final results of the forecasts are shown in Figure 5 and Table 1.

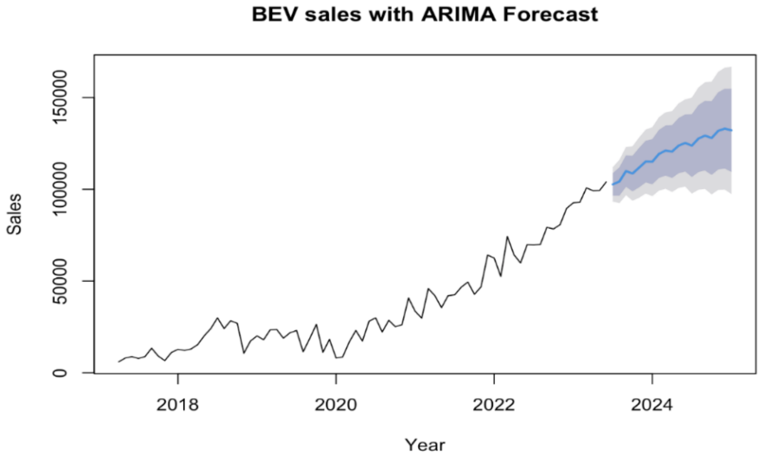

Fig. 5 Visualization of the forecast (original)

Table 1. Fitted values (sales) of the forecast. Unit: US dollars

	Point Forecast	Lo 80	Hi 80	Lo 95	HI 95
Jul 2023	102671.0	96570.44	108771.6	93340.98	112001.1
Aug 2023	104246.5	96557.82	111935.3	92487.66	116005.4
Sept 2023	109926.7	101381.43	118472.0	96857.82	122995.6
Oct 2023	108593.0	98916.43	118269.6	93793.96	123392.0
Nov 2023	111837.3	101124.38	122550.3	95453.28	128221.4
Dec 2023	115127.4	103773.57	126481.2	97763.23	132491.5
Jan 2024	115023.4	102778.20	127268.5	96296.01	133750.7
Feb 2024	119254.9	106202.79	132307.1	99293.41	139216.4
Mar 2024	121111.8	107518.02	134705.6	100321.91	141901.7
Apr 2024	120561.7	106202.79	134919.5	98603.36	142520.1
May 2024	123818.7	107518.02	138848.7	100832.26	146805.1
Jun 2024	125250.2	109736.59	140763.8	101324.19	148976.1
Jul 2024	123796.4	106724.46	140868.4	97687.11	149905.7
Aug 2024	127638.9	109448.44	145829.4	99818.99	155458.8
Sept 2024	129240.1	110262.83	148217.3	100216.89	158263.2
Oct 2024	127952.1	107890.77	148013.5	97270.93	158633.3
Nov 2024	131850.8	110857.45	152844.2	99744.23	163957.4
Dec 2024	133058.0	111363.49	154752.6	99879.09	166237.0
Jan 2025	132130.9	109475.03	154786.7	97481.76	166780.0

3. Result and Discussion

Historically, the development of electric vehicles met its first turning point around 2018, when the rate of growth of the industry first exhibited exponential traits. Notably, the year after, gasoline prices skyrocketed after half a decade of stability, modeling similar percentages to the increase in EV sales. Provided the high correlation between the two, it cannot rule out the probability of a cross-sectional correlation between the two variables, in that consumers in the EV market already expected the increase in the price of gasoline. Nonetheless, such a correlation of expectations had little evidence previous to the period discussed, making it a questionable variable to bring into consideration. However, given possible future fluctuations in Oil Prices, such may be another factor worthy of consideration in the forecast of EV sales.

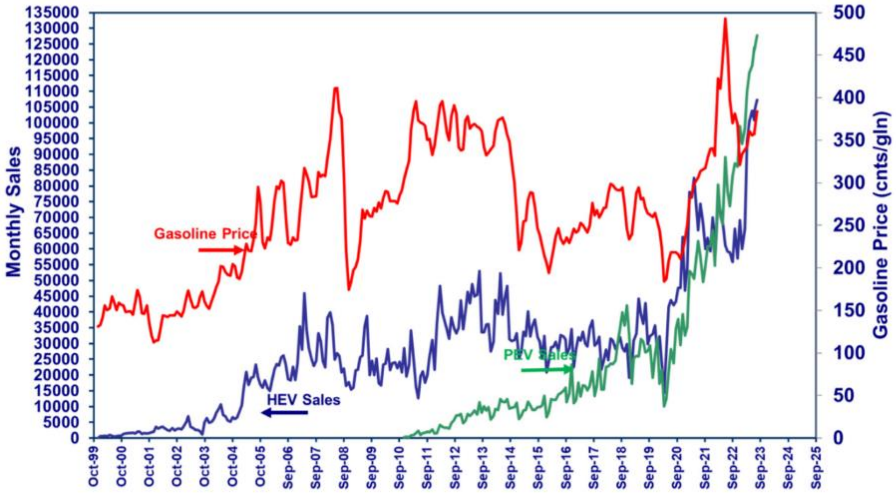

Fig. 6 Monthly EV sales with gasoline price aside (original)

Leaving aside explanatory variables, the model of EV sales based on historical data tells a story of an increasing trend over the foreseeable future. According to the forecast, EV sales will hit 125000 in 2024 and 150000 shortly after 2025 (Figure 6). It is important to note how the forecasted line is concave down, indicating a possible saturation of the market as predicted by the model, further entailing a possible exhaustion of the developmental potential of the market. Such estimation is against the reviewed literature by the group and is considered to be an underestimation of the situation. More generally, the group expects a trend of growth that may be linear, or even positively exponential shortly.

Initially, policy favoring low emissions continues to be established at more and more rapid rates, revealing a trend of emphasis on environmental protection by official agencies. Such is especially true for China and Europe, taking up a major portion of the world market. Additionally, consumer awareness of global warming continues to escalate in also boasting about the environmentally friendly nature of electric vehicles. Overall, increased environmental awareness may function as another factor boosting the development of the EV market. Moreover, embodying frontier technological advancements, the EV market is also likely to inflate by the development of AI and autopiloting as EVs would be the primary target of such novel technology, constituting another variable suggesting the underestimation of the model. In aggregate, the EV market is a blue sea both for future investors and future consumers.

4. Related Studies and Regional Policies Regarding Electric Vehicles

In this section, an examination of studies and regional policies is conducted, focusing primarily on their impact on electric vehicle (EV) sales. Two key dimensions are emphasized: consumer perspectives and the roles of local governments.

Concerning consumers, several factors influencing their interest in electric vehicles are analyzed. Research by Hanna L. Breetz and Deborah Salon investigates pertinent questions, such as whether EV owners experience cost savings and to what extent their competitiveness relies on government subsidies. The study compares battery electric vehicles (BEV), hybrid electric vehicles (HEV), and conventional internal combustion engine vehicles (ICEV). The findings indicate that BEVs are considerably more expensive and rely heavily on government incentives to achieve cost competitiveness. This cost disparity stems from factors such as depreciation, higher sales tax, ad valorem taxes, and insurance costs. Owners seeking cost savings must access free or reduced-rate charging, which is contingent on government subsidies [3].

Additionally, Mee Ryoung Song, Wujin Chu, and Meeja Im's research identifies four psychological factors influencing consumer interest in purchasing EVs: consumer innovativeness, range anxiety, consumer motives, and knowledge of EVs [4].

Consumer innovativeness, defined by Morton et al. in 2016, signifies consumers' inclination to adopt novel products with advanced features [5]. EV adoption, being a form of innovation, presents challenges such as frequent and time-consuming charging, leading to range anxiety or the fear of being stranded [6]. However, test driving mitigates this anxiety. Consumer motivations for car use also impact EV consumption, with considerations such as transportation needs, status signaling, and emotional driving experiences. According to McKinsey and Company's report in 2017, U.S. and German consumers perceive EVs as high-tech, cost-effective, environmentally friendly, quieter, and more enjoyable, with lower maintenance costs. Knowledge about EVs, especially cost comparisons with internal combustion engine vehicles, significantly influences purchase intentions. Research suggests that public awareness is as crucial as monetary incentives, emphasizing the importance of public education efforts.

On the governmental front, local authorities play a pivotal role in promoting EVs and implementing incentives. Research by Shuai Pan et. al underscores the positive impact of widespread EV adoption on air quality and mortality rates. This insight informs national and regional policymakers, aiding them in crafting policies for eco-friendly transportation. The study delves into existing EV policies across regions, focusing on clean transportation goals set by states like California and northeastern regions. The analysis encompasses various policies, technological advancements, and behavioral strategies aimed at overcoming barriers to EV adoption. Due to diverse electricity sources across regions, tailored strategies are essential for achieving sustainable electric mobility [7].

In conclusion, a comprehensive understanding of EV sales necessitates the consideration of both consumer perspectives and governmental policies. By addressing the concerns and motivations of consumers and implementing effective policies, the potential benefits of widespread EV adoption can be maximized.

5. Conclusion

In conclusion, the exploration of the electric vehicle (EV) landscape in the United States reveals a market experiencing rapid growth and transformation. The analysis, based on data from Argonne National Laboratory, showcases a rising trend in EV sales, particularly in the first and fourth quarters of the year. Factors such as discounts, new model releases, and tax incentives significantly influence these fluctuations.

The data analysis of this project, employing ARMA modeling techniques, indicates a consistent upward trajectory in EV sales, with forecasts predicting approximately 125,000 units sold in 2024 and a subsequent increase to 150,000 shortly after 2025. However, the model's concave down curve hints at a possible market saturation, a prediction disputed by some literature suggesting linear or even exponential growth shortly.

Policy initiatives favoring low emissions, coupled with increasing consumer environmental awareness, are identified as key drivers of the EV market. Additionally, advancements in AI and autopiloting technologies are expected to further boost EV development. Despite challenges such as cost disparities and range anxiety, efforts to mitigate these concerns through government subsidies and public education are crucial.

Moreover, regional policies and governmental interventions play a vital role in promoting EV adoption. Studies highlight the significance of tailored strategies based on diverse regional contexts, emphasizing the need for policymakers to address barriers to EV adoption and capitalize on the potential benefits of eco-friendly transportation.

In essence, a holistic approach that considers both consumer perspectives and effective governmental policies is essential to maximizing the benefits of widespread EV adoption. The EV market represents a promising frontier for investors and consumers alike, underscoring the importance of continued research and targeted interventions to sustain its growth and environmental impact.

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