# Exploring Factors that Influenced the Unit Sales of Electrified Vehicles in the US in 2019

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*Using a cross-sectional data set containing information about electrified car models sold in the US, I created an econometric model to explore what factors influenced the unit sales of electrified vehicles in 2019. The results of the regression analysis reveal that Tesla models significantly outperformed the competition in terms of units sold in 2019, South Korean electrified car models underperformed, and the sales of Japanese electrified car models were sensitive to changes in price. Total range, cargo volume, and MPGe were also significant factors that influenced unit sales of electrified car models. Whether an electrified car model was a BEV or PHEV did not influence 2019 unit sales. After providing more background information about electrified vehicles, I review existing literature, lay out the hypothesized econometric model, improve the model and analyze final regression results, and provide implications for automakers and government policymakers.*

## Introduction

For the last century, the automotive industry has been dominated by the gas-powered internal combustion engine. However, times are rapidly changing. Increasingly strict emissions regulations, greater consumer awareness about environmental concerns, government incentives, and rapid advancements in battery technology are significant reasons why automakers are beginning to focus on the development of electrified vehicles.

Historically, electric vehicles, or EVs, have not been popular because of short driving ranges between charges, long recharge times, and the unproven nature of the technology. However, as improvements in battery technology have simultaneously increased range and decreased cost, the world's largest automakers are beginning to develop a new generation of electrified cars.

Toyota plans to generate half of its sales from electrified vehicles by 2025. Volkswagen Group will spend more than $30 billion developing a fleet of EVs by 2023, the same year the company plans to reach its target of one million electric cars sold. Ford recently unveiled the Mustang Mach-E, a fully electric crossover intended to compete directly with Tesla, and promises a lineup of 40 electrified vehicles by 2022. Volvo plans to release a new electrified vehicle every year over the next 5 years, and its first BEV, the XC40 Recharge, will go on sale in the US by the end of 2020. Lastly, Nissan recently launched the Leaf Plus, and plans to introduce 8 new electrified car models by 2022.

In this study, I will discuss two types of electrified vehicles: battery electric vehicles, or BEVs, and plug-in hybrid vehicles, or PHEVs. BEVs are powered by electric motors, as opposed to an internal combustion engine, or ICE, that runs on gasoline. Energy in BEVs is stored in large, high-density batteries, not unlike those in a computer or smartphone, that can be recharged using household electricity. BEVs produce zero tailpipe emissions and are cheaper to operate than their gasoline counterparts. Instead of having to go to a gas station, BEVs can be conveniently charged at home overnight, and with high-speed chargers, their batteries can reach 80% charge in around half an hour.

On the other hand, PHEVs represent a natural stepping stone from ICE vehicles to BEVs. PHEVs use an ICE as well as an electric motor. However, unlike conventional hybrid vehicles, PHEVs can be recharged from an electric vehicle charging station. With larger batteries than conventional hybrids, most PHEVs can be driven for 10-40 miles without using any gasoline, meaning that drivers can travel in all-electric mode for the majority of day-to-day local driving. When the batteries run out of charge, the small ICE powers the PHEV until the batteries can be recharged. Thus, with the same driving range as ICE vehicles, PHEVs eliminate the 'range anxiety' many people experience with BEVs.

Although electric vehicle technology continues to advance rapidly, sales of electrified vehicles in major markets continue to lag behind automakers' mainstream ambitions. Therefore, "it is both timely and important to focus on this segment of the market and interrogate the factors underlying the problem of their [EV's] low market penetration" (Berkeley, 2017). The present study seeks to determine what factors influence US consumers' decisions to purchase electrified vehicles, thus revealing what vehicle characteristics automakers should prioritize when developing new electrified car models, such as price, total and electric-only range, MPGe, horsepower, battery size, or body style. My results will also determine what incentives and policies the US government should consider to increase electrified vehicle sales.

## Literature Review

We begin the literature review by focusing on BEV range. Based on a full year of driving data analyzing daily driving patterns of 484 internal combustion vehicles in the US, Pearre (2011) concludes that an electric range of 100 miles would meet the needs of 32% of US drivers, if they were willing to adapt daily driving patterns 6 times a year. In support of Pearre's findings, Lin's (2014) study "proposes a framework for optimizing the driving range [of BEVs] by minimizing the sum of battery price, electricity cost, and… a measurement of range anxiety" (635). Lin's results strongly suggest that an electric range of 100 miles or less will be popular in the US market in the near future. However, the natural reduction of battery costs will drive BEV demand towards longer ranges while simultaneous improvements in charging infrastructure will drive

BEV demand toward shorter ranges over time. These two factors will drive BEV ranges in opposite directions, each targeting a distinct market segment.

Regarding BEVs in the UK, Berkeley (2017) finds that higher price and the availability of public charging stations are the two most significant barriers to BEV adoption, despite financial incentives and advancements in battery technology over the last decade. Although financial incentives have been implemented in several major automotive markets to lower electrified vehicle prices, research suggests consumers possess limited awareness of these policies. In fact, only 5% of the population in the UK's 21 largest cities are aware of EV incentives. Other barriers to EV adoption that Berkeley identifies include concerns over the durability of the battery, the continued belief that BEVs are an inferior technology, and uncertainty over maintenance, service, and repair infrastructure.

Throughout his Los Angeles case study, Adepetu (2017) focuses on the "impact of a high-capacity battery and EV rebates on an EV ecosystem" (353). In line with Berkeley's conclusions about the significance of BEV price in the UK market, Adepetu concludes that in the sprawling metropolis of LA, BEV price is a more significant barrier to adoption than range. In fact, increasing battery capacity by 500 percent while keeping price constant would likely only increase EV adoption by five percent. Adepetu concludes that policy-makers and auto-manufacturers should focus more on decreasing price than increasing range to promote more widespread EV adoption.

There are several studies that focus on PHEVs and consumer buying preferences versus BEVs and traditional ICE vehicles. Helveston (2015) models consumer preferences for gasoline, PHEV, and BEV technologies in the US. He finds that in the US, "mid-range PHEVs compete more strongly than BEVs against their respective gasoline counterparts. [Furthermore], low-range PHEVs compete most strongly against their gasoline counterparts" (110). Regarding PHEV electric-only range, Kontou's study (2015) reveals that the optimal electric-only driving range of PHEVs is 16 miles. This figure is sensitive to battery cost and gasoline price. Lane (2018) examines different factors that influence potential car buyer consideration for PHEVs or BEVs. He finds that consumers interested in buying a PHEV consider economic benefits, such as reduced gasoline and maintenance costs while those interested in buying a BEV are drawn to its environmental and technological appeal. As mentioned before, the lack of range anxiety for PHEVs is a major factor influencing potential electrified vehicle buyers.

Singer (2016) investigates national consumer views towards PHEVs. 46% of respondents believe that PHEVs are just as good as, or better than, traditional gasoline vehicles, 23% of respondents state they would consider a PHEV for their next vehicle purchase or lease, and 49% of respondents would be willing to pay incremental costs for PHEVs.

A few studies examine the perception of BEVs versus ICE vehicles. Higgins (2017) explores how vehicle body types affect consumer preferences for BEVs. Results show the existence of preconceived notions about BEVs as smaller vehicles with inferior performance. However, in his study two years later, Long proves that Tesla is an exception to this notion. Respondents most frequently associate BEVs with Tesla (27%), Toyota (27%), and Chevrolet (26%). Nearly 70% of respondents possess brand awareness about Tesla, and 40% of those individuals believe Tesla represents the future of BEVs.

Based on the literature review, I hypothesize that electrified car models with a lower price and higher total range sold more units in the US in 2019 than electrified car models with a higher price and lower total range, on average.

**Methodology**

For my econometric analysis, I created a cross-sectional dataset of BEVs and PHEVs sold in the US in 2019. Variables include 2019 units sales, MSRP, total and electric-only range, horsepower, battery size, MPGe, charging time, body style, and country of origin. Every variable (except 2019 sales) applies to base trims. I gathered data from individual manufacturer websites, the EPA (fueleconomy.gov), and Webasto Charging Systems (evsolutions.com). The INSIDEEVs 2019 EV Sales Scorecard provided comprehensive sales data. However, since several automakers do not provide model breakdowns and a few do not reveal EV sales figures at all, INSIDEEVs base some numbers on inventory and historical sales, which nevertheless provide accurate estimates. Descriptions of variables discussed in the econometric analysis are found in Table 1.

Table 1. Descriptions of Variables Discussed in the Econometric Analysis

| **Name** | **Description** | **Coding** |
|---|---|---|
| *SALES* | The number of units of an electrified car model sold in the US in 2019. | Continuous |
| *TSLA* | Whether or not an electrified car model sold in the US in 2019 is a Tesla. | 1 = car model is a Tesla<br>0 = car model is not a Tesla |
| *MSRP* | The base price, in dollars, of an electrified car model sold in the US in 2019. | Continuous |
| *TOTRANGE* | The total range, in miles, of an electrified car model sold in the US in 2019. | Continuous |

| | | |
|---|---|---|
| *MPGE* | The MPGe of an electrified car model sold in the US in 2019. MPGe, or 'miles per gallon gasoline equivalent,' is the metric used by the EPA to measure the efficiency of electric vehicles. | Continuous |
| *CRGOVLM* | The cargo volume, in cubic feet, of an electrified car model sold in the US in 2019. | Continuous |
| *BEV* | Whether or not an electrified car model sold in the US in 2019 is a BEV or PHEV. | 1 = car model is a BEV<br>0 = car model is a PHEV |
| *CROSS* | Whether or not an electrified car model sold in the US in 2019 is a crossover. | 1 = car model is a crossover<br>0 = car model is not a crossover |
| *JPN* | Whether or not an electrified car model sold in the US in 2019 is produced by a Japanese company. | 1 = car model is produced by a Japanese company<br>0 = car model is not produced by a Japanese company |
| *SKOREA* | Whether or not an electrified car model sold in the US in 2019 is produced by a South Korean company. | 1 = car model is produced by a South Korean company<br>0 = car model is not produced by a South Korean company |

Based on the literature and my hypothesis, my initial hypothesized econometric model was:

$$SALES_i = \beta_0 + \beta_1 TESLA_i - \beta_2 MSRP_i + \beta_3 TOTRANGE_i + \beta_4 MPGE_i + u_i$$

Considering Higgins' (2017) conclusion that respondents who possessed brand awareness about Tesla indicated that "Tesla has influenced them to perceive BEVs as more innovative, stylish, and environmentally-beneficial" (185), I expected β1 to be positive. Since Berkeley (2017) found that higher price was one of the two most significant barriers to BEV adoption in the UK, I expected β2 to be negative. This result is further supported by Adepetu's (2017) LA-based study, where he found that BEV price is a much more significant barrier to adoption than electric-only range. However, owing to the fact that a higher total range would help combat the range anxiety consumers experience with electrified vehicles, I also expected β3 to be significant and positive. Lastly, I expected β4 to be positive since many consumers are drawn to electrified vehicles due to their environmental appeal, and therefore should value higher efficiency. Descriptive statistics of variables discussed in the econometric analysis are found in Table 2.

Table 2. Descriptive Statistics of Variables Discussed in the Econometric Analysis

| Name | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| *SALES* | 7,323.11 | 23,891.59 | 24 | 158,925 |
| *TSLA* | .0682 | .255 | 0 | 1 |
| *MSRP* | 52,959.77 | 26,854.95 | 23,900 | 147,500 |
| *TOTRANGE* | 356.68 | 166.09 | 58 | 640 |
| *MPGE* | 89.23 | 27.26 | 43 | 141 |
| *CRGOVLM* | 21.91 | 16.98 | 5.4 | 88 |
| *BEV* | .386 | .493 | 0 | 1 |
| *CROSS* | .364 | .487 | 0 | 1 |
| *JPN* | .136 | .347 | 0 | 1 |
| *SKOREA* | .182 | .390 | 0 | 1 |

**Results**

The regression of my hypothesized econometric model in STATA yielded unexpected results. Although *TSLA* had a positive effect on *SALES* at a 1% level of significance, it was the only independent variable in the model that was significant. *MSRP*, *TOTRANGE*, and *MPGE* were all insignificant, even at a 20% significance level. There had to be a reason why the regression results did not align with my hypothesis or the literature.

After exploring individual observations in the dataset for answers, I uncovered the likely root of the problem: the Tesla Model 3. The Model 3 sold 158,925 units in 2019, nearly 140,000 units more than the second best-selling electrified vehicle (which also happened to be a Tesla). Because of the Model 3's astoundingly high sales, the strong effect of *TSLA* on *SALES* in the hypothesized model simply diminished the importance of all other regressors, rendering them insignificant. Thus, I removed its observation from the dataset and focused on refining the econometric model.

After testing additional combinations of independent variables with the original four hypothesized regressors and running dozens of regressions in STATA, my refined econometric model was:

$$SALES_i = \beta_0 + \beta_1 TESLA_i + \beta_2 MSRP_i - \beta_3 SKOREA_i + \beta_4 CRGOVLM_i + \beta_5 TOTRANGE_i + \beta_6 MPGE_i + u_i$$

Every regressor in the refined econometric model had a significant effect (with the expected sign) on *SALES* at a 5% level of significance or less except for *MSRP*, which was still insignificant even at a 20% significance level. This was perplexing, given the multitude of studies that identify the price of electrified vehicles as a significant barrier to adoption.

The refined econometric model suggested that electrified car models produced by South Korean companies were associated with fewer units sold in the US in 2019 when compared to electrified car models not produced by South Korean companies, ceteris paribus. The model also suggested that an increase in the cargo volume of electrified car models was associated with an increase in their unit sales in the US in 2019, ceteris paribus. Although the refined model yielded two interesting insights, it was critical to continue exploring why *MSRP* did not have a significant effect on *SALES*.

After testing various combinations of interaction terms, my final econometric model was:

$$SALES_i = \beta_0 + \beta_1 TESLA_i + \beta_2 MSRP_i + \beta_3 JPN_i - \beta_4 MSRPJPN_i - \beta_5 SKOREA_i + \beta_6 CRGOVLM_i + \beta_7 TOTRANGE_i - \beta_8 CRGORANGE_i + \beta_9 MPGE_i + u_i$$

Conducting an *F*-test for the overall significance of the regression, all regressors are jointly significant at a .01% significance level, $F(9,33) = 14.79$, $p < .00005$. Furthermore, based on the value of adjusted $R^2$, 74.72% of the variation in unit sales of electrified car models in the US in 2019 is explained by the regression equation, ceteris paribus. The values of coefficients for regressors across all three econometric models discussed in the present study are listed in Table 3.

Table 3. Regression Results for the Hypothesized, Refined, and Final Econometric Models

| **Regressor** | **Hypothesized Model** | **Refined Model** | **Final Model** |
|---|---|---|---|
| *TSLA* | 59522.04<br>(12535.44)* | 7274.23<br>(2890.69)** | 5637.28<br>(2818.013)*** |
| *MSRP* | -.105<br>(.146) | .0116<br>(.0250) | .00329<br>(.0213) |
| *JPN* | | | 36348.84<br>(11668.43)* |

| | | | |
|---|---|---|---|
| *MSRP*JPN (MSRPJPN)* | | | -1.070<br>(.344)* |
| *SKOREA* | | -6376.90<br>(1396.29)* | -5942.74<br>(1396.14)* |
| *CRGOVLM* | | 67.23<br>(32.17)** | 331.04<br>(109.88)* |
| *TOTRANGE* | -.859<br>(17.90) | 7.50<br>(3.054)** | 15.72<br>(5.412)* |
| *CRGOVLM*TOTRANGE (CRGORANGE)* | | | -.611<br>(.238)** |
| *MPGE* | 107.23<br>(153.91) | 137.73<br>(28.94)* | 110.14<br>(27.95)* |
| Intercept | -446.19 | -12273.58 | -13326.26 |
| Adjusted $R^2$ | .414 | .631 | .747 |
| Number of Observations | 44 | 43 | 43 |

**Dependent Variable: number of units of an electrified car model sold in the US in 2019**
Standard errors are given in parentheses under coefficients. Individual coefficients are statistically significant at the ***10%, **5%, or *1% significance level.

Although *MSRP* remained insignificant in the final econometric model, the interaction between *MSRP* and *JPN* has a significant negative effect on *SALES* at a 1% level of significance, ceteris paribus. To determine if I should keep *MSRP* in the model, I performed a joint hypothesis test between *MSRP* and *MSRPJPN*. Based on the results of the *F*-test, *MSRP* and *MSRPJPN* have a jointly significant effect on *SALES*, $F(2,33) = 5.08$, $p = .012$. Thus, *MSRP* remained in the model. Meanwhile, the interaction between *CRGOVLM* and *TOTRANGE* has a significant positive effect on *SALES* at a 5% level of significance. *JPN*, *SKOREA*, *CRGOVLM*, *TOTRANGE*, and *MPGE* are significant at a 1% level of significance, and *TSLA* is significant at a 10% significance level.

Interpreting the coefficients of regressors in the final econometric model, if an electrified car model is a Tesla, the model is expected to sell 5,637 more units in the US in 2019 than an electrified car model that is not a Tesla on average, ceteris paribus. If an electrified car model is produced by a Japanese company, the model is expected to sell 36,349 more units in the US in 2019 than an electrified car model not produced by a Japanese company on average, ceteris paribus. Furthermore, for an electrified car model produced by a Japanese company, if the price of that model increased by $1,000, sales in the US in 2019 would be expected to decrease by 1,067 units on average, ceteris paribus. However, for an electrified car model not produced by a Japanese company, if the price of that model increased by $1,000, sales in the US in 2019 would be expected to increase by 3 units on average, ceteris paribus. The price of an electrified car model is expected to have a much greater effect on unit sales of that model in the US in 2019 if the model is produced by a Japanese company.

If an electrified car model is produced by a Korean company, the model is expected to sell 5,943 fewer units in the US in 2019 than an electrified car model not produced by a Korean company on average, ceteris paribus. Provided that the cargo volume of an electrified car model increased by one cubic foot, sales of that model in the US in 2019 would be expected to increase by 331 units on average, ceteris paribus.

If the total range of an electrified car model increased by one mile, sales of that model in the US in 2019 would be expected to increase by 16 units on average, ceteris paribus. Moreover, for an electrified car model with 500 miles of total range, if the cargo volume increased by one cubic foot, sales of that model in the US in 2019 would be expected to increase by 26 units on average, ceteris paribus. However, for an electrified car model with 200 miles of total range, if the cargo volume increased by one cubic foot, sales of that model in the US in 2019 would be expected to increase by 209 units on average, ceteris paribus. Cargo volume of an electrified car model is expected to have a greater effect on sales of that model in the US in 2019 when total range is lower. On condition that the MPGe of an electrified car model increased by one MPGe, sales of that model in the US in 2019 would be expected to increase by 110 units on average, ceteris paribus.

It may seem unclear why the independent variable *BEV* was not included in the final econometric model. Since the literature states that PHEVs are a natural stepping stone to BEVs from today's gasoline-powered ICE vehicles, one might expect PHEV models to have significantly higher sales in 2019 than BEV models. However, when I added *BEV* to the final econometric model, the regressor was highly insignificant, with a p-value of .641. Further research should be conducted as to why there was no significant difference in BEV and PHEV sales in the US in 2019. My hypothesis is that since we are still in the emerging phase of electrified vehicles becoming mainstream, many early adopters make the leap from ICE vehicles straight to BEVs. Lane's (2018) list of factors that influence potential car buyer consideration for BEVs supports this 'early adopter' hypothesis.

Given the drastic increase in unit sales crossovers have experienced in the US over the last decade, I also wanted to check the effect of *CROSS* on *SALES* in the context of the final econometric model. With a p-value of .654, *CROSS* was highly insignificant. However, given crossovers' practical nature and spacious interiors, some of the effect of *CROSS* is likely captured in the highly significant regressor *CRGOVLM*. I believe that *CROSS* will have a significantly positive effect on sales of electrified vehicles in the US in the future once automakers expand their electrified crossover lineups.

## Conclusion

Several implications for both automakers and government policymakers emerge from the analysis of my final econometric model to increase electrified vehicle adoption. Firstly, even after removing the Model 3 observation, Tesla is still the clear electrified vehicle market leader in terms of unit sales. Like Tesla, other automakers, especially those from South Korea, should work on expanding the perception of their electrified vehicles from just environmentally-beneficial to innovative, sporty, and technologically advanced.

Since unit sales of electrified car models produced by Japanese companies in the US in 2019 were very sensitive to price, Japanese automakers should prioritize keeping the price of future models low. Automakers should also maximize cargo volume in electrified car models with a shorter total range to 'compensate' for the shorter range and positively influence unit sales. Lastly, policymakers should consider imposing emissions regulations on electrified vehicles in the future to increase average MPGe across automakers' lineups, thus boosting appeal for especially environmentally-conscious buyers.

The car industry is at the dawn of a new era, and the question is not if, but when electrified vehicles will dominate the automotive landscape.

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