Infrastructure for Charging Electric Vehicles' Effect on Sales in China: Regional Variations and Policy Implications

Yuqi Chen*

Gui Cheng Senior High School, Foshan, 528200, China

Abstract. The market for electric vehicles in China has grown quickly. However, the impact of the quantity and distribution of charging infrastructure on electric vehicle sales has not been thoroughly investigated. This study examines infrastructure for charging electric vehicles' impact on sales using monthly sales data and charging station data from January 2016 to December 2019. The number of charging stations and sales of electric vehicles have a weak countrywide association, according to regression and correlation analysis. Nevertheless, there is a strong positive association between the quantity of charging stations and the sales of electric vehicles in southern regions like Guangdong and Sichuan, indicating that enhanced charging infrastructure substantially boosts sales. In contrast, in central and northern provinces like Ningxia and Hubei, this effect is more limited, reflecting regional disparities. The study suggests that while improvements in charging infrastructure significantly impact electric vehicle sales in southern regions, other factors such as regional economic development and climate conditions affect northern regions.

1 Introduction

The drawbacks of conventional oil vehicles have come to the notice of an increasing number of individuals in recent years. For example, the exhaust gas emitted by fuel vehicles will pollute the environment and harm human health. The Chinese electric vehicle market has also experienced rapid development [1, 2]. According to the data from the China Association of Automobile Manufacturers, China's electric vehicle sales have increased from 331,092 in 2015 to 9.495 million in 2023, becoming the world's largest electric vehicle market. In China, the swift advancement and widespread adoption of electric vehicles have also been propelled by other factors, such as the continuous improvement of charging devices, which greatly shortens the charging time and increases the endurance time, which makes more people willing to choose electric vehicles [3, 4]. The requirement for charging devices has increased as a result of China's ongoing development of electric vehicles. These devices are essential to the successful operation of electric vehicles, and their availability and quantity have a significant impact on the convenience and user experience of these vehicles [5, 6].

* Corresponding author: keira@ldy.edu.rs

Although by the end of June 2024, China already has more than 10.24 million charging piles, and as early as 2020, China has constructed the largest, most numerous, and most robust service capacity charging pile network in the world, but the charging pile in China still has uneven distribution, insufficient number, and poor performance. In some third- and fourth-tier cities or remote areas such as Ningxia and Tibet, the charging pile distribution density is small, and the coverage rate is low, which greatly affects the amount of electric car sales. Conversely, in many affluent cities like Beijing and Guangdong, there is a high coverage rate, a significant distribution density of charging piles, and a notable rise in the sales of electric vehicles. Nevertheless, the majority of recent studies on the quantity and distribution of charging stations and sales of electric vehicles are done at the macro level and do not provide a thorough examination of individual areas. How the popularity of charging infrastructure in different regions affects the sales of electric vehicles remains to be further studied. In order to support the development of more effective policies and measures to protect the growth of China's electric vehicle market, this paper investigates the impact of the establishment of charging facilities on the market by looking at the relationship between monthly sales of electric vehicles and the quantity of charging piles in various regions of China.

2 Methods

2.1 Data collection and description

2.1.1 Electric vehicle monthly sales data

To gain a thorough understanding of China's electric vehicle market's development trend and its relationship with charging facilities, the monthly sales number for electric vehicles was gathered for this study. The data comes from the number of compulsory traffic insurance policies. Since each car needs a compulsory traffic insurance policy before it is delivered to the user and driven legally on the road, this data can more truly reflect the sales data of each car company and its specific models compared to sales data, and this data does not give the car company a chance to falsify, so the data has high authenticity and comprehensiveness, and can more truly reflect the total value of electric vehicle sales. The data includes the electric vehicle sales on a monthly basis in various regions from January 2016 to December 2019, and this study selects provinces in different regions and at different levels of development for detailed records and analysis.

This data provides the dependent variable (monthly sales of electric vehicles) for the data analysis, and this study can help preliminarily understand the regional differences, seasonal fluctuations, and sales trends of electric vehicle sales by studying the changes in electric vehicle sales in different regions and periods. By collating and analyzing these data, the general outline and development trend of China's electric vehicle market can be roughly depicted.

2.1.2 Charging pile ownership data

To calculate to what extend charge stations affect China's sales of electric vehicles, it is also essential to collect data on charging piles. These data come from the China Electric Vehicle Charging Infrastructure Promotion Alliance, which is an authoritative charging facility data statistics agency in China, and its data has high accuracy and authority. The data includes the monthly charging pile ownership in various regions across the country from January 2016 to December 2019, addressing different kinds of charging stacks including public charging

piles, dedicated charging piles, DC charging piles, AC charging piles, and AC/DC charging piles.

This data provides an independent variable (charging pile ownership). By examining the relationship between the quantity and location of charging stations and the sales of electric vehicles, the conclusion can be inferred whether the quantity and distribution of charging piles have an impact on electric vehicle sales.

2.2 Data analysis

2.2.1 Regression analysis

This study uses a linear regression model for analysis. The monthly sales of electric vehicles are used as the dependent variable (Y), and the quantity of charging piles is used as the independent variable (X). Before performing regression analysis, the data needs to be preprocessed to check the integrity and consistency of the data and deal with missing values and outliers. By constructing a linear regression model, the equation (1) can be obtained:

$$Y = \beta_0 + \beta_1 X + \varepsilon \qquad (1)$$

The intercept term is β_0, the regression coefficient is β_1, which indicates the degree of influence of the change in the number of charging piles on the change in electric vehicle sales, and ϵ is the random error term. Through linear regression analysis, The degree to which the quantity of charging stations and the quantity of electric car sales are correlated can be depicted, and the correlation coefficient can be used to determine whether the two numbers are negatively correlated or positively correlated.

2.2.2 Correlation analysis

In order to confirm the linear correlation between the quantity of charging piles and monthly sales of electric vehicles,this study also conducted a correlation analysis. Correlation analysis is also a commonly used statistical method used to study the degree of association among two or more elements [7].

This study sets the null hypothesis H0 as "The number of charging piles and the monthly sales of electric vehicles do not have a linear relationship.", that is, r=0, and selects a significance level of 0.05. The level of connection between the quantity of charging stations and the quantity of electric car sales can be judged according to the value of the Pearson correlation coefficient (In this article, a high correlation is denoted by $|r|>0.7$, a moderate correlation by $0.4<|r|<0.7$, and a weak correlation by $|r|<0.4$.). Then, the p-value can be obtained by the correlation coefficient r and the sample size n using statistical software or table lookup method, and the result is compared with the significance level (0.05) [8, 9]. It is considered that there is a significant linear association between the number of charging piles and the monthly sales of electric vehicles if the p-value is less than 0.05, rejecting the null hypothesis. On the other hand, if the p-value is higher than 0.05, it is considered that the linear relationship between the two values is not significant and that the null hypothesis cannot be discarded [10]. By calculating the Pearson correlation coefficient and p-value, whether there is a relationship between the quantity of charging stations in each area and the volume of electric car sales, and if so, how strong the relationship is can be determined.

3 Results

In this study, the country and several representative provinces selected from the south, central, and north are analyzed. The following will mainly calculate and analyze the correlation

coefficient and p-value to further explore the relationship between the quantity of charging stations and the quantity of electric cars sold.

As shown in Table 1, the nationwide regression analysis and results show that the P-value=0.06032>0.05, This demonstrates that there is no statistically significant national correlation between the quantity of charging stations and the monthly sales of electric cars. At the same time, the multiple correlation coefficient value of 0.279111, means that the correlation between the quantity of charging piles and the monthly sales of electric vehicles is weak, suggesting that there is little direct correlation between the quantity of charging stations and the sales of electric cars. Furthermore, only roughly 7.79% of the variations in monthly sales of EV can be explained by the number of charging piles, as indicated by the coefficient of determination's value of 0.077903. This shows that the explanatory power of this model is low. Electric car sales across the country is not significantly impacted by the quantity of charging stations. The impact on sales is small.

Table 1. The regression analysis and results in nationwide.

Regression Statistics	
Multiple R	0.279111
R Square	0.077903
Adjusted R Square	0.056946
Standard error	68399.76
Observations	46
variance analysis	

	df	SS	MS	F	Significance F
regression analysis	1	1.74E+10	1.74E+10	3.717333	0.06032
Residual	44	2.06E+11	4.68E+09		
total	45	2.23E+11			

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%	Lower limit 95.0%	Upper limit 95.0%
Intercept	30153.66	22146.84	1.361533	0.180277	-14480.4	74787.68	-14480.4	74787.68
X Variable 1	0.152977	0.079343	1.928039	0.06032	-0.00693	0.312882	-0.00693	0.312882

Table 2 displays the findings of the regression analysis and P-value=0. 232506>0.05 from Beijing. This shows that in Beijing, the effect of charging pile quantity on electric vehicle sales each month is not statistically significant. At the same time, according to the multiple correlation coefficient value of 0.179541, it indicates that there is little relationship between the quantity of charging stations and the monthly sales of electric cars , suggesting that there is little direct correlation between the quantity of charging stations and the sales of electric cars. Furthermore, only roughly 3.22% of the variations in monthly sales of electric vehicles can be explained by the number of charging piles, as indicated by the coefficient of determination's value of 0.032235. This shows that the explanatory power of this model is low. In Beijing, the quantity of charging stations does not influence the sales of electric cars significantly.

Table 2. The regression analysis and results in Beijing.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.179541							
R Square	0.032235							
Adjusted R Square	0.01024							
Standard error	4586.007							
Observations	46							
variance analysis								
	df	SS	MS	F	Significance F			
regression analysis	1	30823494	30823494	1.46559	0.232506			
Residual	44	9.25E+08	21031464					
total	45	9.56E+08						
	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%	Lower limit 95.0%	Upper limit 95.0%
Intercept	4046.888	1705.665	2.372616	0.022099	609.3458	7484.431	609.3458	7484.431
X Variable 1	0.056072	0.046317	1.210615	0.232506	-0.03727	0.149419	-0.03727	0.149419

Aligned with the earlier discussed analytical principles, the regression analysis and results in Ningxia show that the P-value=0.435787>0.05, which shows that in Ningxia, There is not a statistically significant association between the quantity of charging stations and the monthly sales of electric cars. At the same time, according to the multiple correlation coefficient value of 0.117745, it shows there is little relationship between the quantity of charging stations and the monthly sales of electric cars, indicating that there is little direct correlation between the quantity of charging stations and the sales of electric cars. In addition, only roughly 1.39% of the variations in monthly sales of electric vehicles can be explained by the number of charging piles, as indicated by the coefficient of determination's value of 0.013864. This shows that the explanatory power of the model is low. The quantity of charging stations has little influence on how many electric cars are sold in Ningxia.

The regression analysis and results in the Hubei region show that the P-value=0. 12637>0.05. This shows that in Hubei, there is not a statistically significant relationship between the quantity of charging stations and the average monthly sale of electric cars. At the same time, according to the multiple correlation coefficient value of 0.228671, It implies that the relationship between the number of charging piles and the monthly sales of electric vehicles is poor, this suggests that the number of charging sites has a minor direct impact on electric vehicle sales. The coefficient of determination value of 0.05229 indicates that the number of charging heaps can only explain about 5.2% of the changes in monthly sales of Electric cars. This shows that the explanatory power of this model is low. In Hubei, the quantity of charging piles has minor effect on electric vehicle sales.

The regression analysis and results in Guangdong show that the P-value=0. 004831<0.05,and the results in Guangxi shows that the P-value=0. 002112<0. 05 respectively, which shows that in Guangdong and Guangxi Province, the impact of charging pile ownership on monthly sales of electric automobiles is statistically significant. Meanwhile, according to the

multiple correlation coefficient value of 0.408457 in Guangdong and 0. 441824 in Guangxi , it demonstrates that the quantity of charging piles and the monthly sales of electric cars have a somewhat substantial positive association. It also means that the quantity of charging stations will have a big impact on how many electric cars are sold. Furthermore, the coefficient of determination, which stands at 0.166837in Guangdong and 0. 195208 in Guangxi,indicates that variations in the monthly sales of battery-powered cars can be caused by variations in the quantity of charging piles, or roughly 16.68% in Guangdong and 19.52% in Guangxi of the total. Although the explanatory power of the model is not very high, it can already explain part of the changes in sales.

The regression analysis and results in Sichuan show that the P-value=0. 021551<0.05. This shows that in Sichuan, there is a statistically significant relationship between the quantity of charging stations and monthly sales of electric vehicles. At the same time, according to the multiple correlation coefficient value of 0.338107, It points to that there is a lesser collaboration than there is in Guangdong Province between the number of charging piles and the monthly sales of electric vehicles, indicating that there is not much of a direct correlation between the quantity of charging stations and electric car sales. Moreover, given that the coefficient of determination is 0.114317, approximately 11.43% of the variations in the monthly sales of electric vehicles can be explained by the quantity of charging piles. Although the explanatory power of the model is not very high, it can already explain part of the changes in sales.

4 Discussion

From the above regression analysis of data from multiple provinces in the south and north-central provinces, It is evident that:

The results of the regression analysis in the southern provinces indicate that all of the p-values are less than 0.05, indicating that the quantity of charging piles in the region has a major influence on the sales of electric cars and that the popularity of charging piles can increase the sales of electric cars. . The correlation coefficient of Guangdong is greater than 0.4, although the correlation coefficient of Sichuan is 0.338107, which is slightly smaller than Guangdong, It generally demonstrates that there is a somewhat strong positive link between the number of charging heaps and the monthly sales of electric vehicles. There has been an increase in the number of charging piles in the two provinces can explain 16.68% and 11.43% of the changes in electric vehicle sales respectively, It unequivocally demonstrates that one of the main reasons for the rise in popularity of new energy cars is the development of the infrastructure for charging them. In addition to meeting users' needs and making charging more convenient, an adequate quantity and sensible distribution of charge piles can also inspire more people to adopt electric vehicles, hence driving up sales of these vehicles.

In contrast, the regression analysis of the three provinces selected in the north-central part illustrates that all of the p-values are higher than 0.05. Especially in relatively less developed regions such as Ningxia, the p-values can reach 0.435787, which are much greater than 0.05, which shows that there is little relationship between the quantity of charging piles and the sales of electric vehicles in the three central and northern regions, and that the influence on sales of electric vehicles is minimal. Because the correlation coefficients of these three provinces are all around 0.1, which means that the northern and central regions' sales of electric car models are greatly affected by other factors, such as regional economic level, consumer preferences, policy support, and the rationality of the layout of charging facilities, etc., as opposed to the quantity of charging stacks.

The above results show that the association between the number of charging piles and sales of electric vehicles varies significantly between the center and northern regions and the southern provinces. The southern provinces show a stronger correlation, while the central and northern provinces show a weaker correlation. These differences may be affected by the following factors:

The first one is climate factors. The climate in the south is warmer, so the battery performance of electric vehicles is less affected by temperature. This shows that in the south, the use efficiency of electric vehicles is relatively high, and electric vehicle users have more frequent demand for charging piles in daily use, encouraging the building of charging piles. During the bitterly frigid North Central winter, especially in the northeastern region, the low-temperature environment will greatly affect the battery life of electricity-powered cars, restricting the application of electric cars. This could influence buyers' propensity to buy electric cars. In this case, the penetration rate of electric vehicles is low and user demand for charging piles is relatively reduced, resulting in a weak correlation between the quantity of charging stations and sales of electric cars. At the same time, the setting of charging facilities in different regions should meet local needs. For example, southern provinces are relatively hot and humid, so the design and construction of charging facilities may pay more attention to climate adaptability measures such as moisture protection and lightning protection, while the climate in northern provinces is relatively cold and arid. If it is cold, more consideration needs to be given to how to ensure the normal operation of charging facilities in low-temperature environments. Therefore, the construction costs and maintenance costs of the two are also different, which will also affect how many charges there are.

Secondly,the level of economic development is also important. The level of economic development in southern China is generally high, particularly in the Yangtze River Delta, Pearl River Delta and other regions. Residents in these places have higher incomes and strong spending power. Because export trade is relatively developed and they can easily communicate with the world and catch up with the trends of the times, they are more likely to accept and purchase Automobiles with electricity. Concurrently, because electric cars are becoming more and more popular, businesses and municipal governments have the resources and incentive to provide infrastructure for charging them. thus forming a positive cycle: the number of charging stations rises in tandem with the growth in electric car sales. In contrast, in the central and northern regions of China, especially in some economically underdeveloped provinces such as Ningxia, residents have relatively weak consumption power and relatively low demand for electric vehicles. Although the government may also be supporting the building of charging piles, there is a poor association between the two because of the low usage rate of charging piles brought on by the low sales base.

5 Conclusion

In China's electric vehicle market, the correlation between the quantity of charging stations and monthly sales of electric cars is examined, focusing on analyzing the differences in different regions. Through specific analysis of regional data, the relationship between the sheer quantity of charging piles and sales of electric vehicles varies significantly between the south and north central regions, as can be seen. This study found that charging pile infrastructure contributes significantly to the growth of the market for electric vehicles in southern regions. In contrast, in three randomly selected provinces in the north-central region, the correlation between the count of charging piles and the monthly sales of electric cars is weak, and there is even almost no significant correlation in some areas. In summary, there will be notable regional variations in the correlation between the quantity of charging stations and sales of electric vehicles in different parts of China. The driving effect of sales volume is relatively weak.

This conclusion has implications for how to encourage the growth of the electric vehicle market and for the future building of charging stations for electric vehicles. Building infrastructure for charging piles is an important factor in promoting the development of China's electric vehicle market, but its relevance will show significant differences in different regions. Therefore, future market strategies and policies should be adjusted based on the characteristics and the unique requirements of every area to accomplish the thorough and equitable growth of China's electric car industry.

References

1. Cheng, M., & Tong, M, Development status and trend of electric vehicles in China. Chin. J. Electr. Eng. **3(2)**, 1-13 (2017)
2. Khaleel, M., Nassar, Y., El-Khozondar, H. J., Elmnifi, M., Rajab, Z., Yaghoubi, E., & Yaghoubi, E, Electric vehicles in China, Europe, and the United States: Current trend and market comparison. Int. J. Electr. Eng. and Sustain., 1-20 (2024)
3. He, H., Sun, F., Wang, Z., Lin, C., Zhang, C., Xiong, R., & Zhai, L, China's battery electric vehicles lead the world: achievements in technology system architecture and technological breakthroughs. Green Energy and Intell. Transp., **1(1)**, 100020 (2022)
4. Mo, T., Li, Y., Lau, K. T., Poon, C. K., Wu, Y., & Luo, Y, Trends and emerging technologies for the development of electric vehicles. Energies, **15(17)**, 6271 (2022)
5. Das, H. S., Rahman, M. M., Li, S., & Tan, C. W, Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. Renew. Sustain. Energy Rev., **120**, 109618 (2020)
6. Sanguesa, J. A., Torres-Sanz, V., Garrido, P., Martinez, F. J., & Marquez-Barja, J. M, A review on electric vehicles: Technologies and challenges. Smart Cities, **4(1)**, 372-404 (2021)
7. Baak, M., Koopman, R., Snoek, H., & Klous, S, A new correlation coefficient between categorical, ordinal and interval variables with Pearson characteristics. Comput. Stat. Data Anal. **152**, 107043 (2020)
8. Pearson, E. S, The test of significance for the correlation coefficient. J. Am. Stat. Assoc. **26(174)**, 128-134 (1931)
9. Obilor, E. I., & Amadi, E. C, Test for significance of Pearson's correlation coefficient. Int. J. Innov. Math. Stat. Energy Policy, **6(1)**, 11-23 (2018)
10. Learning, L, Testing the Significance of the Correlation Coefficient. Introduction to Statistics (2023)