Proceedings of the 3rd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/106/20241509

The Review on Development of New Energy Vehicles in China: Characteristics, Factors and Impacts

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Abstract: Amidst the mounting environmental challenges posed by energy supply, the ascendancy of hybrid and electric vehicles (EVs) as important instruments capable of curbing greenhouse gas emissions and energy consumption has garnered attention. However, existing reviews largely predate the surge in new energy vehicle sales, and prevailing studies often narrow their focus, yielding gaps in the panoramic comprehension. Moreover, the remarkable surge of the new energy vehicle industry in China, galvanized by robust governmental support and technological strides, remains a relatively untrodden path in scholarly exploration. This article undertakes a comprehensive dissection encompassing the categorization, historical evolution, policy ramifications, and ecological reverberations of new energy vehicles within China. Notably, this work illuminates the interdependent nexus of governmental backing, technological ingenuity, and market forces, underscoring new energy vehicles' substantial contributions to abating carbon emissions and stewarding resource reservoirs. Employing predictive modeling, this study augments understanding by proffering insights into forthcoming ownership trends of new energy vehicles. In sum, this review bridges existing gaps in research, furnishing an all-encompassing vista of the new energy vehicle sector in China and its transformative power.

Keywords: New energy vehicle, Policy, Technology Development, Carbon emission, Predictive model.

1. Introduction

Today, energy supply is posing greater challenges to the environment as it has brought significant impacts on the global environment. Issues like water pollution, air contamination, and ocean pollution, as well as climatic change, have become serious challenges that demand urgent attention and effective solutions [1]. In response to this pressing issue, governments and advocacy organizations have been advocating for less energy consumption and carbon neutrality by actively utilizing hybrid and electric vehicles (EVs) as key components of the technology mix [2-5]. As electric vehicles have emerged as potential solutions to environmental problems, a significant body of research has focused on environmental impact assessments surrounding EVs. Many studies have examined consumer

DOI: 10.54254/2754-1169/106/20241509

attitudes and behaviors to understand the key factors influencing their decision to adopt EVs. Some of these studies have focused on psychological factors influencing consumer attitudes toward EVs, while others have explored factors such as demographics, context, and background [6-13]. Rezvani et al. conducted a comprehensive review of 16 studies on consumer attitudes toward EVs, identifying important determinants affecting consumers' attitudes towards EVs, including social environment, cost, technology, and collective and personal preferences [6]. However, their focus remained limited to psychological factors influencing consumer attitudes. Meanwhile, Coffman et al. examined the influence factors underlying the selection of EVs but neglected the impact of marketing efficiency and mental elements like emotions [7]. Emotional factors play an important role in affecting consumer decision-making, and understanding their role in EV adoption is crucial for developing effective promotional strategies. Javid and Nejat proposed a comprehensive model that examined socio-demographic, situational, and contextual factors of regional EV adoption but ignored psychological factors [9]. Similarly, Liao et al. reviewed the CAVIE literature, focusing on individual habit/choice-related factors but did not provide a comprehensive classification and meta-analysis of these factors [10]. Adnan et al. analyzed 17 studies on the adoption of plug-in hybrid electric vehicles (PHEVs)/EVs. This study also had its limitation that it merely referred to the theory of planned behavior, ignored important factors such as socio-economic considerations, and did not conduct a meta-analysis of CAVIE studies [8]. Gnann et al. studied the proliferation of the Plug-in Electric Vehicles (PEVs) market in Germany and the United States but did not take into account important factors like charging infrastructure, EV range, and battery costs [11]. Meanwhile, Sanguesa et al. provided a comprehensive survey of EV technologies, charging models, and research in various laboratories but did not discuss in-depth associations such as EVs with other cutting-edge technologies and fields [12,13]. Furthermore, the implementation of policy measures such as fiscal incentives, tax incentives, and subsidies has boosted the wider application of new VEs. Investments in charging infrastructure, batteries, and other technologies have also greatly facilitated technological innovations supporting the advancement of new energy vehicles, leading to exponential growth in their popularity over the last decade. Notably, the new energy vehicle industry has experienced remarkable development in China. A report from Xinhua News Agency shows that in 2022 alone, there were a total of 5.35 million registrations of new energy vehicles across the country, occupying 23.05 percent of all new registrations in that year, representing a growth rate of 81.48 percent compared to the previous year. This impressive growth is particularly notable considering the relatively short history since the startup of the new energy vehicle industry in China. In just 50 years, China has transformed from an emerging industry to a global leader in new energy vehicle development and innovation. Now China has become the largest market of new energy vehicles globally, and its automotive industry has already established a comprehensive and mature industrial system. Additionally, it has a robust supply chain and reliable local component suppliers for automotive manufacturing. This makes China an inspiring model for other countries and an ideal area for studying the new energy vehicle industry. Even though China's new energy vehicle industry has achieved remarkable progress, the existing literature about the Chinese market remains relatively scarce and incomplete. In particular, insufficient studies are exploring various aspects of the new energy vehicle market, including consumer attitudes, market penetration, and policy impacts. Besides, the subsequent influence caused by the widespread adoption of new energy vehicles has not been fully considered in the current context. Therefore, future research should more comprehensively and deeply explore the rapid emergence of the new energy vehicle industry in China. In this review, a comprehensive exploration of the classification, historical evolution, and status of New Energy Vehicles (NEVs) in the context of China's dynamic market are presented. Through an exhaustive review of existing literature, this article delves into the key success factors underpinning the NEV industry's remarkable growth and examines the consequential impacts it has engendered. Government policies have emerged as pivotal catalysts in propelling the adoption and proliferation of NEVs among consumers. Robust governmental backing, characterized by an array of fiscal incentives, tax advantages, subsidies, and the implementation of dual credits, has effectively galvanized consumer interest and propelled the exponential expansion of the NEV market. On the technological frontier, the symbiotic development of advanced battery technology and an extensive charging infrastructure has synergistically complemented the ascent of NEVs. This mutually reinforcing relationship has established a virtuous cycle of innovation, bolstering the overall growth trajectory of the industry. The ascendancy of NEVs has reverberated beyond market dynamics, significantly impacting critical aspects of China's socio-economic landscape. Notably, it has yielded substantial reductions in carbon dioxide emissions, curtailed resource consumption, and mitigated the nation's reliance on oil imports. This confluence of factors has played a pivotal role in fostering the advancement and dissemination of China's technological prowess and infrastructural capabilities. Drawing upon the analysis, this article predicts the future ownership trends of NEVs by leveraging the forecasting ability of the Gompertz model. The prognostications, rooted in empirical data and informed insights, furnish valuable perspectives for further research and lay the foundation for illuminating the future trajectory of the NEV landscape.

2. The Characteristics of the New Energy Vehicle Industry and Its Development History in China

2.1. Definition of New Energy Vehicles

New energy vehicles refer to road vehicles with electric propulsion, including the hybrid electric vehicle (HEV), battery electric vehicle (BEV), fuel cell electric vehicle (FCEV), Plug-in hybrid electric vehicle(PHEV), and extended range electric vehicle(EREV).

2.1.1. Battery Electric Vehicles

This type of electric vehicle are completely propelled by using electric batteries without the use of any combustion engine or liquid fuel. This type of vehicle usually has a pack of electric batteries that can be charged to actuate the car. Most BEVs could reach a speed of 160 to 250 km per hour.

2.1.2. Plug-in Hybrid Electric Vehicle

This type of electric vehicle is propelled jointly by conventional combustion engines and electric engines. Electric engines can be charged by connecting the cars with cables that deliver electricity. PHEVs' electric engines can conserve enough electric energy from the cable, which enables them to reduce the amount of fuel used by the combustion engines.

2.1.3. Hybrid Electric Vehicles

Hybrid electric vehicles are similar to the PHEVs since both of them possess electric engines and internal combustion engines. However, unlike PHEVs, HEVs' batteries cannot be charged through the use of outside grids. Instead, they are charged by generating power from an internal combustion engine. And unlike other modern cars, they can even convert kinetic energy, which comes from the energy they generate when they brake, into electricity.

2.1.4. Fuel Cell Electric Vehicles

These types of vehicles do not consume any form of electricity or fuel because their power source is water in the air, which is rich in hydrogen and oxygen to provide them with powerful electricity.

However, the technology is still under development and the performance of fuel cell vehicles cannot be parallel with that of internal combustion engine vehicles.

2.1.5. Extended Range Electric Vehicles.

EREVs are very similar to BEVs mentioned above. The only difference between them is that the EREVs have supplemental engines, which are used for charging batteries whenever they are needed. Unlike HEVs and PHEVs, combustion engines used in EREVs are only used to charge batteries, so these engines are not connected to wheels for propulsion.

2.2. Chinese Electric Vehicles Market

Table 1: Sales of each electric vehicle brand in the first half of 2023.

Brand	Number of car sold(in yuan)
BYD	1,033,616
Tesla	296,478
Volkswagen	57,216
NIO	56,098

The Chinese electric vehicles market is mainly dominated by five brands, inducing BYD, GM, Tesla, GEELY, and CHANGAN, which BYD took 29.7% of the whole Chinese market share. According to the data published by the DianQuDong Benchmarker, the total sales of BYD's electric vehicles reached 1,033,616, while Tesla, the No.2 EV seller, sold 296,478, which is 348% lower than BYD in the first half year of2023. The other popular brands of EV in 2023 include Volkswagen, which sold 57,216 in 2023, and NIO, a Chinese brand that sold 56,098.

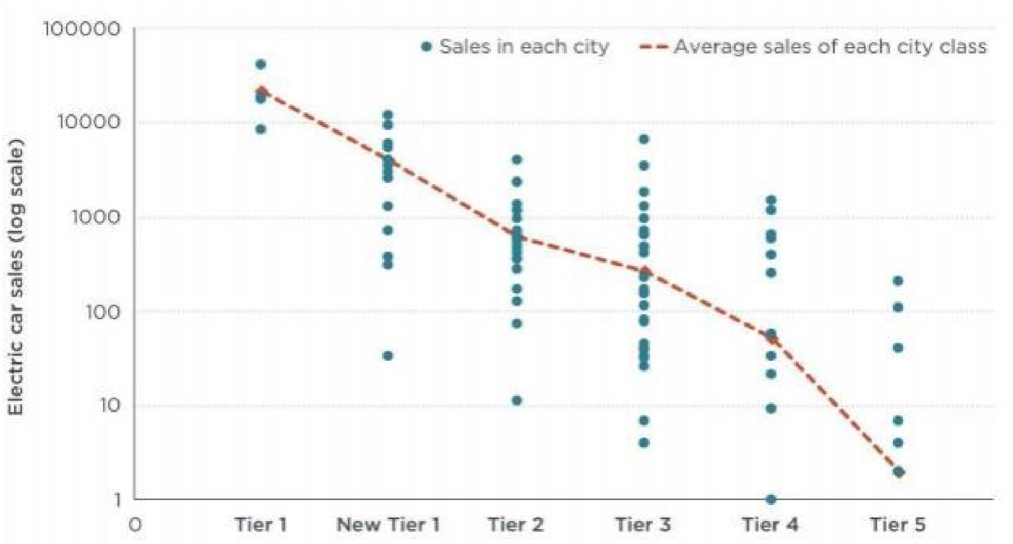

Figure 1: Electric car sales by city class, 2015.

According to Figure 1 created by Hui He and his team, the sales of electric vehicles are disproportionately deployed across cities. The sales of electric vehicles are mainly concentrated in tier 1 cities, which include Shanghai, Shenzhen, Guangzhou, etc, while the sales of cities that belong to other tiers are less. This is clearly illustrated in the graph presented below, which shows an overall decreasing trend in the sales of electric vehicles from tier 1 cities to tier 5 cities. This idea is further strengthened by the data collected by NengYUanHangQing. Shanghai city is the top 1 sales of electric vehicles in China, which sold 208,475 electric vehicles in 2022. The coming cities are Hangzhou city, Beijing city, and Guangzhou city, which are all tier 1 or the new tier 1 cities in China. As the ranking goes down, cities with lower ranking belong to the lower tiers, for example, Xianyang city, a tier 3 city, which had a total of 4199 sales of electric vehicles in 2022, and JiLing city, a tier 4 city, which only had a total sale of 544 electric vehicles in 2022.

2.3. Policy Development history

The reasons behind the disproportionately distributed electric vehicles are factors like the size of cities, the development of cities, and most importantly, the policy support. The supporting policies have evolved through four stages: initial starting, initial formation, quick expansion, and strategic deepening. From 1992 to 2006, China was at its primary stage of developing electric vehicles. In the first stage of initial starting, China included the development of electric vehicles in the eight-five years of national science, which is used for setting long-term projects that will be beneficial for the Chinese economy, and it was included in the technology research plan. The initial forming stage started from 2007 to 2009, in which the project “10 cities each with one thousand NEVs” was launched. The project is about putting 1000 electric vehicles into cities that were selected for the use of public transportation, mail delivery, and government use. This project continued for three years, covering 25 cities in total. During this stage, professionals in this field advocated for formalizing the NEV industry and creating its definition, and NEV was officially launched. Then, from 2010 to 2014, China remarkably pushed the development of the NEV industry policies. At present, with the release of the Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries by the State Council, the other six industries, including the new energy automobile industry, are identified as strategic industries in the new stage of China. To promote their development, the Chinese government has introduced more than 50 supportive policies, manifesting the emphasis of the government on developing the new energy industry. Finally, the Chinese government also changed the policy choice to be made by the new energy vehicle market itself, and the market orientation was changed from the original producer orientation to consumer orientation. Then, the policy development of the new energy vehicle industry entered the strategic deepening stage in 2015, marked by the release of the "Made in China 2025" by the State Council again. At this stage, the strong support of the Chinese government played a significant role in driving China’s new energy vehicle industry to go ahead of many developed countries. The industrial policy focuses more on the specific implementation mode of the segmented industries such as the power battery industry, transportation investment, and infrastructure construction.

3. Factors Affecting the Development of New Energy Vehicle Industry

3.1. Policy Factors

China boasts the largest car market globally, and the growth rate of automobile ownership in China is not decreasing [14]. In addition, given the effectiveness of new energy vehicles in addressing environmental and energy issues, the Chinese government has paid much attention to this industry and recognized it as one of the strategic emerging industries. Therefore, the new energy vehicle industry has gained strong policy support from the Chinese government. Studies on new energy vehicle policy emphasize the analysis of its policy effect and whether it will have an impact on consumers’ willingness to buy. As for the policy effect, Li et al. and other scholars analyzed how governmental policies affected the expansion of electric vehicles using the sophisticated network evolutionary game approach after considering the situation of different network sizes [15]. Moreover, many scholars use empirical methods to study policy effects. For example, Liu et al. prove the important role of the electric vehicle industry’s deployment in motivating individual willingness to buy electric vehicles using the double difference approach [16]. Some researchers employed questionnaire surveys to analyze how new energy vehicle policies affect consumers' purchase intentions. Lin and Wu conducted such a survey among participants living in China's first-tier cities (Shanghai, Beijing, Shenzhen, and Guangzhou), concluding that the three factors, i.e. government subsidies, price acceptability, and vehicle functionality substantially affected respondents' purchase attention in terms of electric vehicles [17]. However, Li et al. believe that the above scholars make obvious errors when empirically evaluating how new energy vehicle policies affect the actual sales of new energy vehicles, because they ignore the information of part of the text-type data, to improve the shortcomings of predecessors. In the case of determining the combination of quantitative data and textual data, they used econometric regression and LDA topic modeling to conclude that hidden topics in the policy documents significantly promoted the sales of new energy vehicles [18].

3.1.1. Subsidy Policy

Since 2010, the Chinese government has committed to stimulating research and development efforts of manufacturers in the new energy vehicle industry. Thus, it has implemented various subsidy policies for new energy vehicles to achieve this goal and attract more potential consumers of new energy vehicles. For instance, by offering car purchase subsidies, the Chinese government creates a good political climate facilitating the development of China's new energy vehicle industry [19]. Furthermore, scholars have also shown great interest in the associations between subsidies and the new energy vehicle industry's development. Some studies believe that government subsidies provide new energy vehicle companies with more research and development funds so that they can strengthen new product research and increase the output of new energy vehicles, thereby attracting more consumers and promoting further development of the new energy vehicle industry. For example, He et al. submitted the panel data of 35 different models of 6 automobile companies developed in the years 2016-2018 into the PVAR model analyzed the model results, and concluded that car purchase subsidies had a positive impact on the sales of high-efficiency vehicles [20]. However, these subsidies hurt low-efficiency in the long run. Another research on the dynamic relationship between government subsidies and new product research intensity of China's new energy vehicle enterprises employed threshold regression and panel regression models [21]. According to their data results, the government's subsidy policy plays a positive role in increasing R&D intensity. On the other hand, some researchers claim that there is no significant relationship between government subsidies and new energy vehicle sales and the new energy vehicle industry's development. For example, Wang et al. studied the relationship between the subsidy policy and consumers' purchase intention and behavior in terms of energy-saving products like new energy vehicles through an investigation of 436 city residents from 22 provinces of China [22]. According to the results of their structural equation model, the subsidy policy for energy-saving products such as new energy vehicles has no obvious influence on people's willingness to buy or consumption behavior. Moreover, Zuo et al. not only obtained a similar conclusion as Wang et al. but also believed that the reason why government subsidies cannot effectively stimulate the sales and growth of new energy vehicles is that there is no effective R&D subsidy decision-making mechanism in China [23]. In their paper, they proposed a very novel decision model based on the three-way decisions theory. They believe that through this model, policymakers can choose the right subsidy recipients, thus avoiding the waste of public resources, subsidy fraud, and other problems.

3.1.2. Tax Policy

Since the "New Energy Law" was promulgated in 2006, the Chinese authority has introduced various preferential tax policies for a range of new energy industries, including new energy vehicles. Therefore, the relationships between tax policies like value-added tax and tax exemption and the sales and development of new energy vehicle industries are becoming a hot research topic among scholars. Ma et al. analyzed the impact of tax exemption on the market share of new energy vehicles using an error correlation model and a multivariate cointegration model, and they concluded that the relationship between them is positive integration [24]. However, some other scholars also support that some tax policies have no significant impact or even restrict the sales and expansion of new energy vehicles. For example, Sun et al. believed that the preferential VAT incentive policy proposed by the Chinese government would hurt the new energy vehicle industry [25]. To prove this, they compared the profits obtained from the preferential VAT incentive policy of different Chinese companies in the new energy vehicle industry. The analysis results using the difference method (DID) proved that the introduction of value-added tax incentive policies led to reduced return on equity (ROE) of new energy enterprises such as those in the new energy vehicle industry. The reason for this situation is that the value-added tax incentive policies have caused the distortion of the industrial chain, and many enterprises have the problem of insufficient motivation for product innovation in research and development. Same as Sun et al., Yang et al. also analyzed how tax and fiscal policies affect the technology innovation of new energy vehicle enterprises by using fixed effects. In their model, they selected the tax burden and the government's financial subsidies as independent variables, and the technological innovation degree of new energy vehicle enterprises as the dependent variable [26]. Based on the analysis results of the model, they concluded that there is no significant correlation between tax policies and new energy automobile enterprises' technological innovation.

3.1.3. Dual Credit Policy

Under the dual-credit policy, each new energy vehicle can obtain a point called new energy positive points, and the way to obtain such points is that new energy vehicle enterprises produce more new models of vehicles, and these vehicles can well pass the state test for driving mileage, energy density, battery quality, and electric energy consumption. For NEV enterprises, this is a good opportunity to obtain additional credit trading income, because the Chinese government allows the NEV industry to sell the new energy-positive credits they have obtained in the credit trading market [27]. Ma et al. studied the correlation between the dual-credit policy and the technological innovation of new energy vehicles by developing a Stackelberg game model and a technological innovation decision model, with the background of the experiment set in the market environment with asymmetric information [28,29]. Through the experimental data, they concluded that the dual credit policy had a positive impact on the technological innovation of new energy vehicle companies. Additionally, they also found that the effectiveness of the dual credit policy was not influenced by information asymmetry, but it would be impaired once the technology preference of consumers decreases, and this weakening effect will become more and more obvious as the market credit price rises. Li et al also stated the same conclusion as Ma et al by using the DID model to verify the impact and they point out that the dual credit policy had a greater positive influence on domestic listed NEV companies in China than on those listed jointly [30]. However, some scholars such as Yang et al. have outlined that the dual credit policy had resulted in the poorer performance of new energy vehicle enterprises in recent years [31]. To verify this point, they constructed the DID model, the analysis results of which proved their assertion that the dual credit policy negatively impacts enterprise performance, and this negative impact would be aggravated as the enterprise invested more costs in the research and development of new products. This impact on state-owned enterprises is more serious and long-term than that on

DOI: 10.54254/2754-1169/106/20241509

civilian-owned enterprises. At the same time, considering the limited market capacity, combined with the competitive nature and profit gaming between CFV manufacturers and new energy vehicle manufacturers, the competition density game model of CFV manufacturers and new energy vehicle manufacturers is constructed to simulate the evolution and growth of the vehicle market size in China. Xie et al. pointed out that the credit price can effectively drive the new energy vehicle industry to grasp a large market share in their early stage of growth, but as time goes by, the growth rate will be lower and lower until the final high credit price cannot significantly promote the new energy vehicle industry to seize a higher market share [32].

3.2. Technology Development Factor

In recent years, the new energy vehicle industry has made remarkable breakthroughs in many aspects, such as power batteries, public charging infrastructure, vehicle operating systems, and other technologies. Their development also indirectly improves the quality and market competitiveness of new energy vehicles [33]. For instance, Mao et al. claimed that the development of new energy vehicle-related technologies such as the technology used to generate marine energy power can drive the advancement of the new energy vehicle industry because it can provide powerful energy for new energy vehicles [34]. Same as Mao et al, Zhang et al also believed that promoting the development of related industrial technology can facilitate the progress of the new energy vehicle industry [35]. For example, there were certain defects in the wired plug-in technology of trams in the past, which sometimes caused unnecessary accidents. But with the introduction of new energy tram wireless charging technology, the defects of the past wired charging technology such as the aptness to spark, poor wear resistance, poor flexibility, and maintenance difficulty have been effectively solved. In addition, Meng and Jin not only obtained the same conclusion as Zhang et al., and Ma et al. but also constructed a model that can improve the comprehensive development ability of new energy vehicles in China. This model evaluated the development ability of 15 Chinese new energy vehicle enterprises using the improved mutation progression approach and entropy approach. They believe that although China has the largest new energy vehicle market in the world, it lacks core technologies related to new energy vehicles. If Chinese enterprises continue to rely on new energy vehicle technologies from other developed countries, rather than choosing independent innovation and development, they will lose the fast-growing new energy vehicle market [36].

3.2.1. Battery Development

Lithium phosphate batteries are the main material of power batteries applied to new energy vehicles globally, so it can be said that the performance of lithium batteries will directly affect the development of the new energy electric vehicle industry [37]. Scholars such as Li and other scholars believe that lithium-ion batteries will replace other battery systems like nickel metal hydride batteries and lead-acid batteries and become the key power source of new energy vehicles [38]. The reason is that lithium-ion batteries can be recycled twice, and their principle is to rely on ions moving back and forth between positive and negative electrodes to generate electricity to power the car. In the field of new energy vehicles, lithium-ion batteries have specific strengths such as high working voltage, high energy density, quick charging, long cycle life, small size, lightweight, no memory effect, and no pollution. Zhang et al came to the same conclusion earlier than Li, and compared with Li, the patent application data of EV battery technology adopted by Zhang is more detailed and comprehensive, which enables him to carry out a more detailed analysis from the perspective of the overall trend of new energy vehicle battery patents, the distribution of new energy vehicle battery patent types and the integration of multi-disciplinary technologies [39]. However, benefiting from technological progress, scholars began to propose some new batteries to replace lithium batteries. For example, Popien et al. take a consistent system boundary and analyze the life-cycle sustainability of 10 batteries. Moreover, they analyze the performance of these batteries under four different environmental settings, i.e. human toxicity, climate change, photochemical oxidant formation, and mineral resource depletion). Finally, after comparing their respective economic performance indicators (total battery cost), it is concluded that solid-state battery has better performance in terms of safety, energy density, and cycle life than lithium ion battery [40]. Moreover, researchers like Tian et al., also proposed the idea of replacing lithium-ion batteries with sodium-ion batteries which possess the same strengths as lithium-ion batteries, and sodium-ion batteries do not contain lithium, cobalt, or copper, which means that the price is relatively low, and the resource reserves of sodium are much more abundant than lithium [41]. However, regardless of solid-state batteries or silicon ion batteries, they all have some problems more or less. For example, Popien et al., explicitly mentioned in their article that solid-state battery is still in the research stage, and the final data of Tian et al., also showed that although sodium-ion battery has better economic benefits than lithium battery, their energy density is weaker than lithium battery.

3.2.2. Public Charging Infrastructure

At present, there are three categories of most common charging infrastructure, including public charging infrastructure, private charging infrastructure, and semi-public charging infrastructure. Private charging facilities mostly refer to charging poles like those installed in private garages that are used only by one person or family. Public charging infrastructure is installed in public parking lots and underground garages in shopping malls for public use. Semi-public charging facilities usually refer to those charging devices that can only be used by certain people, and they are usually installed in the underground parking lots of certain enterprises and the parking lots of some public institutions to facilitate the use of their employees. In recent years, many scholars have believed that public charging facilities are more popular with EV owners because most Chinese families do not have private charging equipment such as a home charging pile, so public charging facilities become the first choice for most PHEV owners, and high power public fast charging units also rationalize the service level and minimize the social cost [42]. Based on this, Wang et al. proposed that installing more public charging equipment plays a crucial role in increasing the sales quota of electric vehicles [43]. To test this conjecture, they constructed an agent-based model, incorporating personal differences between electric vehicle consumers and manufacturers, and defined the parameter Settings according to the Chinese market. The data from their model also show that if the Chinese government can invest more money to build public charging facilities in more areas, the proportion of electric vehicle users in the total car users in China will rise from 23.58% to 39.38% by 2040. Xie et al obtained the same observations as Wang et al. through an investigation using the Advanced Vehicle Technology Market Acceptance (MA3T) model produced by Oak Ridge National Laboratory. Xie et al. find that when cities are equipped with more public charging facilities, consumers preferring the US Light Vehicle (LDV) also have a higher acceptance of BEVs [44]. However, the current inadequate coverage standard of public charging infrastructure is also considered by some scholars as a major barrier to the generalization of EVs. For example, Kleiner et al. (2018) established a computational model by referring to the cumulative electric vehicle sales in Germany and the number of public charging facilities in Germany [45]. Considering the spatial resolution of administrative regions, it was found that although the deployment rate of public charging stations in Germany has been declining, this has not affected the sales of electric vehicles in Germany. On the contrary, its sales have an upward trend. In 2022, He et al studied the public charging infrastructure in Hong Kong, China, and found that the phenomenon mentioned by Kleiner et al also exists in China, and then they established an improved EV charger model conforming to the local situation, incorporating carefully derived supply and demand restrictions, and tested this model on the Hong Kong case [46]. Based on the model and its results, they propose three suggestions for optimizing the spatial deployment of public charging facilities to improve coverage :(1) significantly expand the existing charging network to meet the high need of the increasing number of new energy vehicle users; (2) Neighborhoods and suburbs adjacent to the city should also be rapidly extended to the charging network; (3) It is more economical to install more charging piles in the existing public charging stations than to build more charging stations in the city center.

4. Impacts of Increasing Nev Adoption in China

When searching for the keywords: “impacts, results, consequences, new energy vehicle adaptation” in the Google Scholar and Jstor search engines, the majority of relevant literature investigates the environmental and social impacts caused by the wider adoption of new energy vehicles in China. More precisely, how it impacts China’s greenhouse gas emissions, level of resource reliance, its dependence on foreign oil imports, and its effects on other Chinese industries.

4.1. Environmental impacts

When examining the net environmental implications of a heightened adoption of new energy vehicles (NEVs), a comprehensive life cycle perspective is crucial, as underscored by Wang et al. [47]. Life cycle assessment models furnish an exhaustive evaluation of the environmental efficacy spanning all facets of NEVs. In this context, a life cycle analysis model is used for the systematic scrutiny of the environmental ramifications of a product in its whole life cycle, encompassing the selection of essential raw materials, production, allocation, utilization, and eventual disposal, as articulated by the Rochester Institute of Technology. An illustrative investigation undertaken by Yuan et al. delved into the influence of NEV adoption on China's aggregate carbon dioxide emissions and energy consumption. By formulating a logistic curve-based model that encapsulated fossil energy consumption and greenhouse emission intensity for both NEVs and conventional internal combustion engine vehicles (ICVs), the study aimed to quantify the disparities in greenhouse gas emissions and energy consumption intensities between the two vehicle categories [48]. The study's findings indicated that NEVs when powered by electricity sourced from renewable resources, exhibit diminished greenhouse gas emissions compared to ICVs. However, when NEVs draw power from non-renewable resources, they emit approximately 13.49% more greenhouse gasses compared to their ICV counterparts. Nonetheless, it's imperative to acknowledge that the current energy landscape plays a pivotal role in shaping NEVs' environmental impact. With more than 60% of China's electricity generation originating from coal, the foreseeable trajectory suggests that NEV adoption within the short-to-midterm might not achieve its maximum environmental potential. This inference aligns with the conclusion reached by Huo et al., who emphasized that NEVs can genuinely alleviate China's greenhouse gas emissions only if the nation's electric grid pivots toward sustainable energy sources. The transition to a sustainable grid is deemed pivotal to fully harness the environmental benefits promised by NEVs and to realize their potential as a transformative force in curbing emissions in the Chinese transportation sector [49].

4.2. Impacts on other industries

The sharp diffusion of NEVs in China, spurred on by government subsidies, has become a catalyst for technological advancements and innovation within various industries [50]. Demand for NEVs has spurred intensive battery research and development endeavors by Chinese researchers and corporations [51]. These endeavors have yielded enhancements in battery chemistry, energy density, and charging efficiency, translating into batteries with extended ranges, rapid charging capabilities, and overall more dependable and affordable battery packs [52]. Simultaneously, the charging

DOI: 10.54254/2754-1169/106/20241509

infrastructure sphere has burgeoned in China to accommodate the burgeoning EV fleet. Innovations in charging station technologies have been geared toward amplifying charging speeds, streamlining user convenience, and exploring wireless charging paradigms [53]. Additionally, strides in smart grid integration and energy management systems have emerged to optimize charging patterns and mitigate grid strain. Moreover, a pronounced emphasis on lightweight materials and vehicle design has come to the fore as EVs proliferate. In pursuit of augmented energy efficiency and extended driving ranges, Chinese researchers and manufacturers have ventured into pioneering materials like carbon fiber composites and aluminum alloys, effectively trimming vehicular weight without compromising structural robustness [54]. The surge in new energy vehicle (NEV) adoption in China, propelled by government subsidies, has ignited a profound ripple effect across multiple industries. This phenomenon has not only expedited technological progress and innovation but has also engendered a holistic transformation within the automotive landscape.

5. Forecasting Ownership of New Energy Vehicles in China

There exist numerous methods of predicting NEV sales, including regression models, Bass models, and gray prediction models. Each model has its own merits and limitations. Bass models, for instance, are effective in mathematically representing the initial adoption of new technologies; however, it only work best after inflection points on the graph [55,56]. On the other hand, regression models emerge as a powerful ally in understanding the complexities of NEV sales forecasting. While they may not fully encapsulate non-linear trends, they offer a straightforward approach that facilitates the identification of correlations between variables [57]. This simplicity translates into ease of application and interpretation, which is invaluable in research and industry contexts. Furthermore, the adaptability of regression models allows for the incorporation of diverse factors, enhancing their capacity to generate nuanced insights. It's noteworthy that the versatility of regression models extends beyond linear relationships – by integrating an exponential element, these models can effectively capture and represent non-linear equations, thereby enabling the exploration of more intricate and realistic dynamics within the NEV market. Consequently, my approach to predicting NEV adoption will involve the utilization of a regression model to establish a connection between NEV ownership and another relevant variable. Subsequently, leveraging the projections derived from this correlated variable, I intend to formulate predictions for NEV ownership trends in China. A linear regression model derived and tested by Ruoso et al, 2020 represents the regression pattern of EV share in a b b2 b3 particular country as NEV *sh*are = b0 × GDP × REc × PPG with b0, bı, b2, b3 being coefficients estimated by Ruoso et al, 2020, and having values of 0. 1244, 0.6528, 0.4423, and 3.3809 respectively. GDP represents the GDP per capita of the particular country, REC represents the proportion of the country's energy consumption coming from renewable sources, and PPG is the pump gasoline price. It is unable to access secondary forecast data for China's REC and PPG, so this work is only able to forecast NEV share according to GDP per capita, which is presented in Table 1 below. By substituting data forecasts of GDP per capita, presented in Table 2, it can obtain a rough estimate of the direction of NEV share in China.

Table 2: China's GDP per capita and its percentage change from the previous year (Statista).

Time (year)	GDP per capita (USD)	Change from the previous year
2022	12813.77	-
2023	13721.05	907.28
2024	14800.65	1079.6
2025	15901.1	1100.45
2026	17082.89	1181.79

Table 2: (continued)

2027	18316.86	1233.97
2028	19622.73	1305.87

This paper assumes that REC and PPG will stay constant; however, in reality, they are expected to grow. Under the assumption, that since the exponent above GDP (b1) is 0.6528, the NEV share is expected to increase along with GDP per capita.

6. Conclusion

The future of New Energy Vehicles (NEVs) shines with transformative potential, fueled by technological breakthroughs, evolving consumer preferences, and a global commitment to sustainability. Anticipating the road ahead, NEVs are poised to ride a wave of continuous innovation, with advancements in battery technology and energy density promising extended range and faster charging. A diverse array of NEV offerings, from sedans to specialized vehicles, will cater to varied consumer needs and accelerate integration into industries. An extensive charging infrastructure, coupled with wireless and ultra-fast charging technologies, will alleviate range concerns and bolster adoption. NEVs will play a pivotal role in curbing emissions and reducing environmental impact, spurred by increasingly stringent regulations. This growth will usher in economic opportunities, enhance energy security, and contribute to a cleaner future. As a global phenomenon, the NEV revolution will see collaborative efforts on international standards and shared research, driving a worldwide shift toward sustainable transportation. Addressing challenges such as battery disposal and resource sustainability through continued research and cooperation will further ensure a promising NEV landscape. In summary, the horizon of NEVs brims with optimism, poised to reshape personal mobility, industries, and environmental stewardship for a more sustainable future.

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