

A Data-Driven Analysis of Electric Vehicle Adoption: The Role of Geographic, Economic, and Policy Factors

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Abstract:

The increasing environmental concerns and the need for sustainable transportation have accelerated the shift toward electric vehicles (EVs) across the globe. This study explores the adoption patterns of EVs, with a particular focus on plug-in hybrid electric vehicles (PHEVs), by analyzing a structured dataset containing variables such as vehicle specifications, pricing, electric range, geographic distribution, and eligibility for government incentives. The primary objective is to understand how geographic conditions, economic factors, and policy measures influence consumer preferences and adoption behavior.

Using data preprocessing techniques, exploratory data analysis, and interactive dashboards developed in Power BI, the study identifies key relationships between critical variables affecting EV adoption. The analysis indicates that consumers are highly influenced by factors such as vehicle affordability, driving range, and accessibility to charging infrastructure. Additionally, government interventions in the form of subsidies, tax benefits, and regulatory support significantly contribute to increased adoption rates, especially in urban regions with better infrastructure availability.

The findings of this research provide meaningful insights for policymakers to design more effective incentive programs and expand charging infrastructure in underserved areas. Furthermore, automotive manufacturers and energy stakeholders can utilize these insights to align their product offerings and services with evolving consumer expectations. By adopting a data-driven approach, this study contributes to a deeper understanding of EV adoption dynamics and supports the ongoing transition toward cleaner and more sustainable mobility solutions.

1. Introduction

The global transportation sector is undergoing a significant transformation as electric vehicles (EVs) emerge as a sustainable alternative to conventional internal combustion engine vehicles. This transition is primarily driven by rising environmental concerns, the depletion of fossil fuel resources, and advancements in clean energy technologies. Governments and industries worldwide are increasingly promoting EV adoption to reduce carbon emissions and achieve long-term sustainability goals. Among the different types of EVs, plug-in hybrid electric vehicles (PHEVs) serve as an important intermediate solution by combining electric

propulsion with traditional fuel systems, offering both efficiency and flexibility to consumers.

In recent years, the adoption of EVs has witnessed rapid growth due to improvements in battery technology, reductions in manufacturing costs, and increased public awareness regarding environmental issues. Supportive government policies, including subsidies, tax incentives, and infrastructure development programs, have further accelerated this growth. As a result, EVs are gradually becoming a practical and attractive option for a wide range of consumers.

However, despite this progress, the adoption of EVs is not evenly distributed across different regions. Urban areas tend to exhibit higher

adoption rates due to better access to charging infrastructure and higher consumer awareness, while rural regions often face limitations in terms of infrastructure and accessibility. Economic factors such as income levels, vehicle pricing, and cost of ownership also play a crucial role in influencing consumer decisions. Additionally, variations in policy implementation across regions create differences in adoption patterns.

This study utilizes Power BI as a data visualization and analytical tool to examine the impact of geographic, economic, and policy-related factors on EV adoption. By analyzing real-world data, the research aims to identify meaningful patterns and trends that can support informed decision-making for policymakers, manufacturers, and other stakeholders. The insights generated from this study contribute to the development of effective strategies for promoting sustainable transportation and accelerating the transition toward electric mobility.

1.1 Challenges

Although the adoption of electric vehicles (EVs) is increasing steadily, several challenges continue to slow down their widespread acceptance, especially in the case of plug-in hybrid electric vehicles (PHEVs). These challenges are not limited to technology but also include infrastructure, financial constraints, and consumer perception, making the transition more complex.

Inadequate Charging Infrastructure: One of the most significant barriers to EV adoption is the insufficient availability of charging stations. Many regions, particularly rural and semi-urban areas, lack reliable charging networks, which limits the practicality of EV usage for daily and long-distance travel.

Range Anxiety: A major psychological concern among consumers is the fear that the vehicle may run out of battery before reaching a charging point. Even though technological advancements have improved battery performance, this concern still

affects purchasing decisions.

High Purchase Cost: The initial cost of EVs, including PHEVs, is generally higher than conventional vehicles due to battery and technology expenses. This creates affordability issues, especially for middle- and lower-income groups, despite lower operational costs over time.

Battery and Environmental Concerns: Issues related to battery life, replacement cost, recycling, and environmental impact of battery production continue to raise concerns among potential buyers. These factors influence long-term trust in EV technology.

Limited Consumer Awareness: A lack of proper information and awareness about EV benefits, performance, and cost savings leads to hesitation among consumers. Misconceptions and resistance to change further slow down the adoption process. Addressing these challenges requires a collaborative approach involving government initiatives, technological advancements, and awareness programs to create a supportive ecosystem for electric mobility.

2. Objectives

2.1 To Analyze Geographic and Economic Influences on Electric Vehicle Adoption:

This objective aims to examine how variations in geographic conditions and economic factors influence the adoption of electric vehicles, particularly plug-in hybrid electric vehicles (PHEVs). It focuses on understanding how elements such as regional infrastructure availability, urban–rural differences, income levels, and vehicle pricing impact consumer preferences and purchasing behavior. By using Power BI for data visualization, the study seeks to identify patterns, trends, and relationships that explain differences in adoption rates across locations. The insights derived from this analysis can help in designing targeted strategies to improve EV adoption in regions with lower

penetration.

2.2 To Evaluate the Effectiveness of Policy Measures on Consumer Preferences:

This objective focuses on assessing the role of government policies and incentives in shaping consumer decisions regarding electric vehicle adoption. It examines the impact of measures such as subsidies, tax benefits, rebates, and investments in charging infrastructure on consumer willingness to adopt PHEVs. The study analyzes how different policy frameworks influence market growth and consumer confidence in EV technology. The findings are intended to provide recommendations for policymakers to enhance the effectiveness of existing initiatives and develop more efficient strategies to promote sustainable transportation.

3. Literature Review

Adnan et al. (2017) conducted a comprehensive review and found that consumer adoption of electric vehicles is strongly influenced by behavioral factors, infrastructure availability, and perceived usefulness of the technology. The study emphasized that lack of charging facilities remains a primary barrier.

Machado et al. (2023) highlighted that government incentives and policy support significantly contribute to the growth of EV adoption. Their findings indicate that subsidies and tax benefits play a crucial role in reducing financial barriers for consumers.

Bryła et al. (2022) demonstrated that consumer decisions regarding EV adoption are influenced by access to charging infrastructure and economic incentives. The study also emphasized the role of awareness in shaping positive consumer attitudes.

Langbroek et al. (2016) examined the impact of policy measures and concluded that non-financial incentives, such as access to special lanes and free parking, can also motivate consumers to adopt EVs.

Pamidimukkala and Kermanshachi (2023) identified key barriers to EV adoption, including technological limitations, high costs, and insufficient infrastructure, suggesting that overcoming these challenges requires integrated policy and technological solutions.

Liao, Molin, and van Wee (2017) analyzed consumer preferences and found that driving range, cost, and availability of charging stations are among the most critical factors influencing EV purchasing decisions.

Hardman (2019) focused on the role of recurring and non-financial incentives, concluding that long-term policy consistency and consumer awareness significantly enhance EV adoption rates.

Coffman, Bernstein, and Wee (2017) reviewed global EV adoption trends and emphasized that infrastructure development and supportive policy frameworks are essential for accelerating market penetration.

Sierzchula et al. (2014) found that countries with strong financial incentives and well-developed charging infrastructure experience higher EV adoption rates compared to others.

Narassimhan and Johnson (2018) highlighted the importance of demand-side policies and infrastructure investments, concluding that both factors together are necessary to achieve large-scale EV adoption.

4. Methodology

This study adopts a data-driven and quantitative approach to examine the factors influencing electric vehicle (EV) adoption, with a focus on geographic, economic, and policy-related variables. Power BI is utilized as the primary tool for data visualization and analysis to extract meaningful insights.

Data Collection

The research is based on secondary data collected from publicly available sources, including electric vehicle registration datasets and government reports. The dataset contains relevant variables such as vehicle make and model, manufacturing

year, electric range, base price, geographic location, and eligibility for government incentives. These variables provide a comprehensive foundation for analyzing adoption patterns.

Data Preparation

Before analysis, the dataset was preprocessed to ensure accuracy and consistency. This included handling missing or incomplete values, correcting inconsistencies in formats (such as location codes), and organizing the data into meaningful categories. Variables such as vehicle price and electric range were grouped into ranges to simplify interpretation and improve visualization outcomes.

Analysis Techniques

Power BI was used to develop interactive dashboards and visual representations of the data. Various techniques such as bar charts, pie charts, and geographic maps were applied to identify trends and relationships between variables. Correlation analysis was conducted to examine the impact of factors such as pricing, range, and policy incentives on EV adoption.

Rationale

The use of Power BI allows for dynamic and user-friendly exploration of complex datasets. It enables clear visualization of patterns and supports better understanding of how different factors interact to influence EV adoption. This approach ensures that the findings are not only data-driven but also practical and easy to interpret for decision-making purposes.

5. Results and Discussion

The analysis of electric vehicle (EV) adoption patterns provides valuable insights into how geographic, economic, and policy-related factors influence consumer preferences, particularly in the case of plug-in hybrid electric vehicles (PHEVs). The use of Power BI enabled clear visualization of trends and relationships within the dataset.

5.1 Results

Geographic Variation: The analysis shows that EV adoption is significantly higher in urban and developed regions where charging infrastructure is more accessible. Areas with well-established networks of charging stations demonstrate greater consumer confidence and higher registration rates compared to less developed or rural regions.

Economic Influence: Vehicle pricing plays a crucial role in adoption patterns. The findings indicate that relatively affordable EV models attract a larger number of buyers, while premium models are mostly preferred by high-income groups. This highlights the impact of income distribution on consumer decision-making.

Policy and Incentives: Government incentives such as subsidies, tax reductions, and CAFV eligibility were found to positively influence EV adoption. Regions offering consistent and attractive policy benefits showed noticeably higher growth in EV registrations compared to areas with limited support.

Electric Range Preference: Consumers tend to favor vehicles with higher electric driving range, as it reduces dependency on frequent charging and addresses concerns related to range limitations. Vehicles offering better range performance demonstrate stronger market acceptance.

5.2 Discussion

The results clearly indicate that EV adoption is influenced by a combination of multiple interconnected factors. Geographic accessibility to charging infrastructure remains one of the most critical determinants, as it directly impacts the convenience of using electric vehicles. Regions lacking adequate infrastructure experience slower adoption rates, highlighting the need for targeted investments.

Economic factors also play a vital role, as high initial costs continue to limit accessibility for a broader population. Although long-term operational savings exist, the upfront cost remains a key barrier. Therefore, reducing purchase costs

through subsidies or affordable models can significantly enhance adoption.

Furthermore, government policies act as a strong driving force in shaping consumer behavior. Well-designed and stable policy frameworks not only reduce financial burden but also build trust in EV technology. In contrast, inconsistent policies may create uncertainty and slow down adoption.

Overall, the findings suggest that a balanced approach involving infrastructure development, financial support, and technological improvements is essential to accelerate EV adoption. Collaboration among stakeholders is necessary to address existing challenges and create a supportive ecosystem for sustainable transportation.

6. Conclusion

This study presents a detailed analysis of electric vehicle (EV) adoption patterns with a specific focus on plug-in hybrid electric vehicles (PHEVs), using a data-driven approach supported by Power BI. The research highlights the key factors that influence consumer preferences, including geographic accessibility, economic conditions, and government policy measures.

The findings indicate that geographic location plays a crucial role in determining EV adoption levels. Urban areas demonstrate higher adoption rates due to better availability of charging infrastructure and greater awareness among consumers. In contrast, rural regions continue to face challenges related to limited infrastructure and accessibility, which restrict the growth of EV usage.

Economic considerations were also identified as a major influencing factor. The relatively high upfront cost of EVs remains a barrier for many consumers, particularly in lower-income groups. However, the availability of affordable models and financial incentives can significantly improve accessibility and encourage wider adoption.

Additionally, the study emphasizes the importance of government policies in shaping consumer

behavior. Incentives such as subsidies, tax benefits, and infrastructure investments have proven to be effective in promoting EV adoption. Consistent and well-structured policy frameworks help build consumer confidence and support long-term market growth.

In conclusion, accelerating the transition toward electric mobility requires a comprehensive and coordinated approach involving policymakers, automobile manufacturers, and infrastructure providers. Expanding charging networks, reducing vehicle costs, and strengthening policy support will be essential to overcome existing challenges. The insights derived from this research can assist stakeholders in developing effective strategies to promote sustainable transportation