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Socio-Economic and Demographic Factors Affecting Adoption of Electric Vehicles in India

Swaraj Patil

Abstract: ***The purpose of this study is to analyze the diverse socio-economic and demographic determinants that impact the adoption and growth of electric vehicles (EVs) in India. Quantitative research was conducted utilizing data from the Prowess IQ database. Growth of Electric Vehicles (GEV) is represented through the proxy of total income of ten prominent Indian EV manufacturing companies for eight years from 2016 to 2023. This is analyzed against nine independent variables including GDP, Per Capita Income, Age of Company, Population Density, Average Petrol/Diesel Price, Price of Electricity Per Unit, Average Household Electricity Consumption, and Vehicle Electricity Consumption, data for which was extracted from governmental and company websites. The study employed statistical methods, such as correlation and regression analysis, to examine the associations between the dependent and independent variables. The results depict notable positive correlations with GDP, per capita income, age of company, and population density, and negative correlations with the price of electricity and diesel. Regression analysis further substantiated six variables (population density, petrol prices, per capita income, GDP, diesel prices, and average household electricity consumption) as statistically significant contributors to GEV in India These findings point towards the need to leverage the positive drivers and mitigate the effects of negative correlates. Policies offering financial support tailored to demographic and economic contexts, might help achieve accelerated and sustainable growth for EVs in India. This study highlights the unique impact of demographic elements like population density on the EV market in India.***

Keywords: Electric Vehicles, Growth Factors, Socio-economic Variables, Indian EV Market, Population Density.

I. INTRODUCTION

The widespread use of electric vehicles (EVs) on a worldwide scale has shown an evident curve, marked by visible differences in adoption rates between developed and emerging economies. Established nations, such as Norway, have achieved extraordinary market penetration, wherein EVs accounted for an impressive 79 percent of new car sales in 2022. Conversely, developing countries such as India, while in the early stages of integration, displayed a nascent yet promising growth, with EVs comprising approximately 2 percent of new car sales during the same period.

One of the many benefits of EVs is their tendency to reduce greenhouse gas emissions, which is essential for preventing climate change. Additionally, EVs are becoming an increasingly compelling option for environmentally conscious consumers and forward-thinking policymakers due to their ability to lessen dependence on fossil fuels and the potential for reduced operational expenses due to decreased fuel consumption and maintenance costs. The adoption of electric vehicles (EVs) is influenced by many factors, as shown by studies in various countries. Studies in China have found that EV purchase behaviour is affected by gender, age, and income (Yue et al., 2010), vehicle performance and convenience of use (Tian & Zhuo, 2014, [52]), external influences, incentive policies, and inherent characteristics of vehicles, chargers' density and license plate fee (Wang et al., 2017, [29]), as well as traffic management policies, subsidies, and greenhouse gas emissions (Ding, 2017). Studies in USA and Europe have pointed at these factors as well as various other socio-economic variables that affect EV adoption (Jia and Chen, 2021, [28]). In contrast, in emerging economies like India, research identified vehicle performance barriers, financial barriers and lack of charging infrastructure facilities as the major factors in the adoption of EVs (Lidwin et. al, 2022, [35]). These diverse findings illustrate the intricate interplay of infrastructure, policy support public awareness and socio-economic variables in the global adoption of electric vehicles. Extensive research has been conducted to identify the various factors that influence the adoption of electric vehicles in different nations over the years, but the Indian context has received relatively little attention. This highlights the need for more localized and tailored research in this quickly evolving field.

The transformation of education, lifestyle, and cultural norms, coupled with shifts in macro-economic factors, is poised to reshape the landscape of electric vehicle adoption in India. These changes are likely to influence consumer preferences, infrastructure development, and government policies, thereby altering the key determinants of EV adoption in the country (Chawla, Mohnot, Mishra, Singh & Singh, 2023, [11]).

A comprehensive study of the factors influencing EV adoption in an emerging economy like India can provide invaluable insights for policymakers, enabling them to formulate targeted strategies that promote widespread EV adoption. This, in turn, can harness the benefits of reduced emissions, energy security, and economic growth while positioning the nation leading the way in solutions for sustainable mobility.

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**Correspondence Author(s)*
Swaraj Patil*, Department of Economics, Eklavya School Ahmedabad, Ahmedabad (Gujarat), India. E-mail: swaraj2401.p@gmail.com, ORCID ID: 0009-0001-2509-7190

A nuanced understanding of how diverse factors influence EV adoption in India is crucial for informed policymaking, as it allows for the identification of parallels and distinctions with other nations, enabling policymakers, advisors, and organizations to craft effective, context-specific strategies to drive EV adoption and sustainable transportation in the country. As far as the researcher is aware, there is a paucity of research pertaining to this topic within the Indian context. This study therefore seeks to identify the factors that influence the adoption of electric vehicles in India. To be more precise, the investigation tackles the subsequent research question:

RQ1: What are the socio-economic factors that affect adoption of electric vehicles in India?

The structure of the paper is as follows. The following section provides a comprehensive literature review on electric vehicles and their drivers in India and around the globe. The subsequent section elaborates on the adopted research methodology. The results of the econometric analysis performed utilising data from India then follow. Next, the conclusions drawn from the findings are provided. The discussion section concludes with a discussion of the study's practical implications, limitations, and future research directions. The paper is organized as follows. The next section deals with an in-depth literature review of electric vehicles and its drivers world-wide and in India. The next section discusses the research methodology adopted. This is followed by the findings of the econometric analysis conducted using data from India. The conclusions from the findings are presented next. Finally, the discussion section provides the practical implications of the study, limitations and further scope for research.

II. LITERATURE REVIEW

A. Meaning and Evolution of EVs

Electric vehicles (EVs) have emerged as a transformative mode of transportation within the automotive industry, prompting extensive research endeavors. These devices are characterized by their user-friendly operation, reduced number of moveable components, and lower heat generation. These systems often exhibit more efficiency, ranging from 85% to 90% efficiency, compared to alternative options. Additionally, they possess environmentally sustainable attributes, higher torque capabilities, and exhibit rapid start-up and shutdown characteristics. The EV industry is expected to have significant growth over time, paralleling the advancements made in various renewable energy systems. Within the given context of sustainable urban planning, electric vehicles (EVs) are employed as a means of transportation owing to the previously discussed benefits. Numerous proposals have been put out regarding alternative-powered vehicles, including plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), fuel cell electric vehicles (FCEVs) and battery electric vehicles (BEVs), and. In recent years, there has been a notable increase in the attention given to electric vehicles, which has resulted in a consistent rise in their popularity. Although battery-electric vehicles have experienced significant growth in recent times, it is important to note that they are not a new concept (Alami et al., 2022, [2]). The origins of electric vehicles may be traced back to the experiments conducted by Jedlik Anyos in 1828. However, it was not until 1881 that engineer and inventor Gustave Trouvé developed a rechargeable electric vehicle, following the introduction of viable secondary batteries. By the year 1900, electric vehicles (EVs) began to garner significant attention, leading to a notable rise in the quantity of EV producers and the diversity of EV models available in the market. In the year 1912, the United States witnessed a registration count of 33,842 electric vehicles. However, this marked the zenith of their prevalence, as internal combustion engine vehicles rapidly gained momentum shortly thereafter (Morimoto, 2015, [41]). EVs saw a resurgence and gained prominence in 2006 (Bakker et al., 2012, [5]), following a period of initial enthusiasm in the 1990s. During this year, several notable companies made significant strides towards (re)introducing EVs to the market. Tesla, for instance, introduced the Roadster, while Mitsubishi unveiled the Colt EV concept. Additionally, major automotive manufacturers such as GM, Toyota, and Daimler initiated the development of plug-in hybrid vehicles. Recent studies have demonstrated the rapid growth of electric vehicles (EVs) within the past few years. Based on the worldwide EV outlook report compiled by the International Energy Agency, the global sales of plug-in hybrid electric vehicles and battery-electric amounted to 2.1 million units. The primary obstacles impeding the widespread adoption of electric vehicles are mostly attributed to the high costs associated with battery replacement and the availability of spare parts, as indicated by a study conducted by (Alkhalidi, Malkawi, and Amano, 2021, [3]). Over the past several years, there has been a considerable increase in the number of sales of electric vehicles. Sales of electric cars (EVs) have increased at a rate of more than 70 percent from 2017 to 2018 and are projected to see a phenomenal increase of more than 120 percent between the years 2020 and 2021 (IEA, 2022). Multiple automotive manufacturers have expressed their aim to achieve a sales volume exceeding 15 million units of electric vehicles by the year 2025. It is projected that the increase in sales of electric vehicles would have a direct impact on the price reduction of batteries during the next few years. One of the most significant advantages of electric vehicles is that they do not release any harmful pollutants while they are operating. This contributes to a decrease in the amount of greenhouse gases emitted by the transportation sector. When it comes to cutting greenhouse gas emissions, the transport industry offers the best bang for the buck. This is supported by the steady decrease in costs associated with electric vehicles (EVs) and the impending price parity of electric vehicles and internal combustion engines (ICEs) (Sioshansi & Webb, 2019, [49]). Laberteaux & Hamza (2018, [32]) examined the influence of electric vehicle (EV) utilization on greenhouse gas (GHG) emissions. The research focused on the driving behaviours of 2910 individuals who owned automobiles, as recorded in the California Household Travel Survey.

The findings revealed that both hybrid electric cars (HEVs) and plug-in hybrid electric vehicles (PHEVs) exhibited a reduction in GHG emissions ranging from 2 to 2.5 times when compared to internal combustion engines. The decrease in greenhouse gas emissions (GHGs) shown a notable increase as driving behaviour increasingly resembled that of urban driving, particularly surpassing the reductions achieved by hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) by a factor of three to six. Ke, et al. (2017, [54]) conducted a study that examined the carbon dioxide (CO2) emissions associated with electric cars (EVs) throughout the entire energy supply chain, encompassing the well-to-wheels (WTW), well-to-tank (WTT), and tank-to-wheel (TTW) stages. This comprehensive analysis accounted for the emissions generated by power plants responsible for generating the electricity utilised in recharging EV batteries. The adoption of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) in Beijing in 2015 resulted in a significant reduction in carbon dioxide (CO2) emissions. Specifically, the shift from coal to natural gas power plants contributed to a decrease of 32% and 46% in CO2 emissions when compared to internal combustion engine vehicles (ICEVs), particularly multi-purpose fuel injection (MPFI) vehicles. Electric vehicles (EVs) do not produce any emissions when in operation. However, the emissions associated with EVs are predominantly attributed to the processes involved in material mining, extraction, and battery production, which often occur outside urban areas. Electric vehicles (EVs) have the potential to mitigate pollution levels in urban areas, so contributing to the improvement of human health.

Additional benefits of electric vehicles encompass the presence of incentives and legislative measures that effectively stimulate and augment the pace of electric vehicle adoption. Numerous nations across the globe have implemented subsidies as a means of providing incentives to mitigate the financial burden associated with electric vehicles (EVs). Norway serves as a remarkable example of how laws can effectively enhance the rate of electric vehicle (EV) adoption. According to Broadbent et al. (2018), [7] in the year 2016, EVs accounted for 30% of the total new car sales in Norway. In addition to these measures, Norway has also introduced several other incentives and policies, including complimentary public parking, free battery recharging facilities, and exemptions from public road tolls. According to Liu et al. (2021, [38]), electric vehicles exhibit significantly enhanced acceleration capabilities and reduced maintenance and operational costs. Moreover, in comparison to internal combustion engine vehicles (ICEVs), electric cars (EVs) exhibit notably superior energy efficiency. The majority of the energy supplied by the battery pack is converted and transmitted to the wheels, resulting in fast acceleration.

B. Adoption of EVs Globally

Since the first introduction of the first contemporary Plug-in Electric Vehicles (PEVs) to the United States car market in 2010, namely the Chevy Volt and the Nissan Leaf, all prominent automotive manufacturers have since unveiled at least one PEV alternative. Battery electric vehicles (BEVs), which operate solely on electrical power stored in a battery, are poised to be at the forefront of next releases in the United States automotive market. Plug-in hybrid electric vehicles (PHEVs), characterised by their dual battery and combustion engine architecture, are positioned at the lower end of the chronological spectrum (Carley, Siddiki & Nicholson-Crotty, 2019).

The EV industry has grown rapidly over the last decade thanks to the combined efforts of the corporate and public sectors. Global EV sales (3.24 million) grew by 43% in 2020 compared to 2019, [57], representing 4.2% of the global vehicle market. The worldwide EV stock will have reached 10.9 million by the end of 2020 (MOFCOM, 2021, [24], [25], [40]). The United States and China, the third-largest automobile markets globally after the European Union, are currently witnessing electric vehicle (EV) industry trends that are compelling European manufacturers to embrace the technology (Pavlínek, 2023, [44]). Khatua, Kumar & De (2023) found that around the world, EV sales trends are encouraging. Chinese producers hope to sell 35% of EVs by 2030. China, the United States, and Europe account for 90% of global electric car (EV and plug-in vehicle) sales (IEA, 2021).

China has the largest EV market in the globe. The number of electric vehicles (EVs) sold in China amounted to 2.91 million in 2021, with a current EV stock of 6.4 million (CBIRI, 2022, [10]). Norway aspires to be a leader in the electric vehicle industry by 2025, when it will have achieved the status of zero-emission status for all newly marketed lightweight vehicles. In 2021, [18], 64.5% of the Norwegian automobile market was comprised of battery electric vehicles (BEVs), indicating that Norway has only recently emerged as a BEV market (Yang, Liu, Yang, & Lu, 2023, [58],[59]). Favourable regulations are crucial to the expansion of electric vehicles. Programmes that offer incentives to consumers who buy cars with CO2 emissions of 60 g/km or less are referred to as "Eco-bonus" programmes in Italy (Mpoi, Milioti & Mitropoulos, 2023, [42]); the "Road to Zero Strategy 2020" programme exempts older vehicles with high CO2 emissions from excise duty consumption and provides a subsidy for household chargers in the United Kingdom; tax exemptions in Norway; and the "I move electrically" programme that promotes the use of electric vehicles. Despite financial and non-financial incentives being provided in many countries across the globe, the adoption of electric vehicles remains very low (Bhat & Verma, 2023, [6]). Loengbudnark et. al (2022, [39]) found that in Australia, EVs account for barely 1% of total sales. Yet, no substantial policy advancements encouraging EV adoption have occurred at the national level, with just a few new policies implemented at the state level. As of 2020, there were 12 passenger BEV vehicles, 350 public fast charging stations and about 2,000 public standard charging stations, representing a 40% growth over the previous year (July 2020, [56]). However, no FCEVs are commercially accessible (Dowling 2020, [16]).

In Brazil, only about 23 thousand light-duty electric vehicles (LDEV) were registered between 2011 and 2019 compared to almost 26 million light-duty vehicles (LDV) sold, including ethanol, petrol and flex fuel models in the same duration (ANFAVEA, 2020, [4]). Setiawan, et. al. (2022, [47]) highlighted that there are a few options for EVs on the Indonesian four-wheeler market, ranging from battery electric vehicles (BEVs) to hybrid electric vehicles (HEVs). However, in comparison to vehicles powered by internal combustion engines, their sales have been insignificant. Only 854 EVs, or 0.08% of the market, were sold in Indonesia in 2019. Many emerging countries have a larger share of electric two-wheelers. In India, for example, the proportion of two-wheelers is over 80%. The Indian government is investing heavily in public charging infrastructure through various initiatives. Consumers in affluent countries valued home charging facilities more than public charging infrastructure (Bhat & Verma, 2023). The considerable variations in the adoption of EVs in various countries leads to the need for determining the various market enablers for EVs.

C. Factors Impacting Adoption of EVs

a. Purchase Cost

Cost is a key obstacle for EV adoption (Coffman et al. 2017, [14]). Research has shown that financial incentives had a beneficial impact on EV adoption. While consumers are ready to pay high prices for alternative fuel cars that are more fuel efficient than standard vehicles, BEV and FCEV would only be in demand if there were significant subsidies as well as tax credits and rebates (Jenn et al., 2020, [26]). Rietmann and Lieven (2019, [45]) concluded that purchase price and monetary incentives positively impact the percentage of the market share for EVs and that EVs are more prevalent in nations with larger governmental incentives. Similarly, Hardman et al. (2017) found that offering purchase incentives was an efficient way to boost the market share of hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs).

b. Perceived Benefits

The perceived advantages to the consumers must be compelling enough to outweigh the perceived drawback for the new technology to be successful (Carley et al. 2019). Along with being more fuel efficient, EVs need less maintenance and are less expensive to maintain than traditional cars and fuel efficiency is considered as the most enticing feature of EVs, with the reduced maintenance cost coming in second (Egbue & Long, 2012, [48]). Regarding the social advantages, EV are seen as environmentally benign owing to the lack of petroleum usage and subsequent reduction in vehicle emissions. The environmental performance of EVs has a bigger impact on attitudes and intentions to buy than price and range (Yang et al. 2023). EVs have lower car emissions, which lead to improvement in air quality (Kumar et al., 2021, [31]), cause lowered fine particulate matter (PM2.5) and associated mortality and emit less noise which was seen as a substantial benefit by drivers (Bühler et al., 2014, [8]).

c. Safety Concerns

Past studies have revealed that support for EVs is adversely correlated with safety concerns (Hardman et al. 2017, [19]). BEVs have reportedly caught fire and exploded while being charged or when parked. Additionally, following a car collision, the damaged batteries may relight, necessitating a substantial amount of water to put out the fire. More critically, there are currently no established protocols for putting out BEV fires (Christensen et al., 2021, [13]).

d. Technical Factors

Battery capacity and price of batteries is an important aspect in determining the profitability of BEVs (Egbue & Long, 2012). Adoption hurdles frequently arise from misconceptions regarding driving range, charging times, and the accessibility of charging stations (Hardman et al. 2017), battery life, and depreciation (Liao et al. 2017, [34]). Battery warranty has a beneficial impact on BEV adoption among Chinese consumers. Insufficient hydrogen infrastructure, worries about hydrogen's potential fossil fuel origin, the difficulty to recharge at home, and safety worries about hydrogen storage are all obstacles to the adoption of FCEV (Hardman et al., 2017).

e. Driving Range and Charging Infrastructure

The driving range of a PEV battery on a single charge is one of the main disadvantages (Hardman et al. 2017; Coffman et al., 2017). The length of time it takes to charge the battery (Hardman & Tal, 2018, [20]) and the location of chargers (Coffman et al., 2017) were found to be major adoption barriers. Driving range anxiety was made worse by a shortage of charging stations and a lengthy charging process (Coffman et al., 2017). Stakeholders from the UK, Germany, Austria, Spain, and the Netherlands opined that a substantial impact on adoption will result from a well-developed charging infrastructure (Santos and Davies, 2020, [46]).

f. Socio-Demographic Factors

The effects of socio-demographic traits are crucial in determining whether EVs are adopted. Studies in Australia, Malaysia, Japan and Russia showed that persons with greater incomes, automobile ownership (Lin & Tan, 2017, [36]) and greater education had more in-depth knowledge about and favourable perceptions of EVs. Age was also found to affect customer preferences for EVs in Australia (Ghasri et al., 2019) and compared to younger and older persons, the middle-aged group was more likely to acquire EVs. According to Tiwari et al. (2020, [53][60]), persons with their own cars were more likely to embrace BEVs in the future than persons utilizing public transportation. FCEV purchasing intention was found to be highly influenced by environmental understanding, attitude, subjective norms, and perceived behavioural control (Al-Amin et al., 2016, [1]). Li et al (2017) also found population density related with increased EV sales. Haustein and Jensen (2018, [22]) contrasted traditional and EV users to better understand the variables influencing EV adoption in Denmark and Sweden based on an analysis of sociodemographic and found battery EV users to be male, well educated, having high salaries, and frequently owning several vehicles. Lin and Wu's (2018, [37]) research in China's first-tier cities found that gender, income level, age, marital status, level of education, and region influenced EV adoption.

However, the influence of demographic characteristics including age, education level, and income may vary by nation. Hence, it is essential to consider the various studies that have sought to examine EV adoption in different countries.

D. Factors Affecting EV Adoption in Different Countries

a. USA

Jia and Chen (2021) studied EV adoption patterns in Virginia and established that gender, charging infrastructure, and education were key contributing variables. Carley et al. (2013, [9]) analyzed the factors influencing the purchase behavior of 2302 early EV purchasers in 21 largest urban areas in the USA and found that the early adopters were sensitive to environmental factors, but the main effective factors were purchase cost, driving range, and charging time. Ouyang et al. (2019) found that price was an important influential factor, as decrease in price promoted the development of the EV market most effectively. De Gerardo (2019, [15]) confirmed that price was the main determinant of potential consumers' choice of EVs.

b. Europe

Researchers in Europe discovered that location, charging infrastructure, sociodemographic and psychological characteristics had a substantial influence on early EV adoptions. Thogersen and Ebsen (2019, [51]) hypothesised that in Denmark, the main cause was people's ignorance of the rapidly advancing EV technology and charging infrastructure. According to Higueras-Castillo et al. (2021, [23]), individuals in Spain may be more ready to use EVs if EV technology, incentive policies, and dependability are improved. According to Haustein et al. (2021, [21]), adoption of BEVs in Denmark and Sweden could be increased by expanding charging infrastructure. Similar findings about the impact of public charging infrastructure preparedness on EV adoption were made in Sweden and Denmark (Haustein et al., 2021). In Norway (Simsekoglu, 2018), Denmark (Haustein and Jensen, 2018), and Sweden (Haustein and Jensen, 2018), higher household income is associated with a higher likelihood of purchasing an EV. Studies in Norway have discovered that BEV adoption rose with wealth, income, and education (Fevang et al., 2021, [17]). In Spain, younger women with higher incomes were found to be inclined to buy an EV (Higueras-Castillo et al., 2020).

c. China

Studies in China (Liu et al., 2021) discovered that vehicle pricing and usage, financial incentives, and convenience factors had a substantial influence on EV adoptions. Lin and Wu (2018) revealed that the two most significant variables influencing the desire to acquire a BEV were pollution concern and vehicle pricing based on a survey conducted in four Chinese megacities. Ji and Gan (2022, [27]) discovered that giving young customers (under 40 years age) information on five-year total ownership costs might improve their propensity to purchase BEVs.

Recent studies have found that EV purchase behaviour is affected by gender, age, and income, vehicle performance and convenience of use (Tian & Zhuo, 2014), incentive policies, external influences, and inherent characteristics of vehicles, chargers' density and license plate fee (Wang et al., 2017, [33],[55]), as well as subsidies, greenhouse gas emissions and traffic management policies (Ding, 2017). Financial incentives were discovered to be a less significant driver in EV adoption than the building of charging stations and exemption from buying restrictions (Liu et al., 2021).

d. Thailand

Manutworakit & Choocharukul (2022) demonstrated that performance expectations, environmental concern, social influence, effort expectations, and hedonic motivation significantly and favourably impacted purchase intention of EVs.

e. India

Patyal et al. (2021, [43]) and Tarei et al. (2021, [50]) found EV performance, total ownership costs, and the availability of charging infrastructure as factors affecting EV adoption in India. Kumar et al. (2021) shown that EV demand and market share may be greatly increased by investing in charging infrastructure and giving EV users incentives. Other studies found that improvements to the car itself and localization of the battery, which lowers the cost of EV manufacture, were essential for EV adoption (Chhikara et al., 2021, [12]). Thus, the existing literature points at various technical, environmental, regulatory and socio-economic factors that affect EV adoption across the world. In the Indian context, there is a paucity of research examining the socioeconomic factors that influence EV adoption. This study therefore seeks to identify the socioeconomic factors that influence the adoption of electric vehicles in India.

III. RESEARCH METHODOLOGY

A. Data

a. Data Sources

This study uses data on the total income of ten Indian companies manufacturing electric vehicles (both four-wheelers and two-wheelers) in India for the last eight years spanning 2016 to 2023. This data has been taken from the Prowess IQ database. Data related to age of the company and vehicle energy consumption was taken from each company's website. Data about socio-economic variables was collected from government websites.

b. Variables

i.Dependent Variable

In line with answering the research question, the dependent variable used in this study is the *Growth of Electric Vehicles (GEV).* The proxy variable used to measure GEV is the total income of the top ten companies manufacturing electric vehicles in India, as this is a reasonable indicator of the growth of the sector itself. The companies that were part of the study are shown in Table 1.

Table 1: List of Companies

Sr. No.	Company Name
1	Ather Energy Pvt. Ltd.
2	Bajaj Auto Holdings Ltd.
3	Hero Electric Vehicles Pvt. Ltd.
4	Hyundai Motor India Ltd.
5	J B M Auto Ltd.
6	Mahindra & Mahindra Ltd.
7	Okinawa Autotech Intl. Pvt. Ltd.
8	Olectra Greentech Ltd.
9	Piaggio Vehicles Pvt. Ltd.
10	Tata Motors Ltd.

ii.Independent Variables

The nine independent variables for the study have been derived from the review of existing literature. The final list of independent variables comprised of: Gross Domestic Product (GDP), Per Capita Income (INR), Age of Company (in years), Population Density (per sq. km.), Average Petrol Price (INR), Average Diesel Price (INR), Price of Electricity Per Unit (INR per kwh), Average Household Electricity Consumption (kwh) and Vehicle Electricity Consumption.

c. Summary Statistics

Table 2: Descriptive Statistics of Dependent and Independent Variables

Variable	Mean	Median	Max	Min	SD	Obs.
Vehicle Electricity Consumption	41.43	18.35	144.00	1.5	53.65	80
Price of Electricity Per Unit (INR per kwh)	5.96	6.08	6.47	5.43	0.38	80
Population Density (per sq. km.)	421.88	422.77	434.60	407.22	9.00	80
Average Petrol Price (INR)	81.98	77.66	105.41	62.51	15.71	80
Per Capita Income (INR)	127.53	126.41	170.62	94.8	22.87	80
Gross Domestic Product (GDP)	2390.23	2769.27	3750.00	2294.8	440.99	80
Average Diesel Price (INR)	74.65	73.63	96.67	53.33	15.66	80
Average Household Electricity Consumption (kwh)	1186.75	1179.00	1327.00	1075	73.79	80
Total Income Of Consumer (INR)	168905.00	8062.70	888365.20	2.4	257572.10	80
Age Of Consumer	34.70	23.00	78.00	1	27.16	80

B. Findings

a. Correlation Analysis

Table 3: Correlation Analysis

Variable	Vehicle Electricity Consumption	Price of Electricity Per Unit (INR per kwh)	Population Density (Per sq. km.)	Average Petrol Price (INR)	Per Capita Income (INR)	Gross Domestic Product (GDP)
Vehicle Electricity Consumption	1	-0.036021	-0.033543	-0.028452	-0.029664	-0.025752
Price of Electricity Per Unit (INR per kwh)	-0.036021	1	0.918749	0.913653	0.772078	0.742881
Population Density (per sq. km.)	-0.033543	0.918749	1	0.918228	0.945163	0.912965
Average Petrol Price (INR)	-0.028452	0.913653	0.918228	1	0.803471	0.859494
Per Capita Income (INR)	-0.029664	0.772078	0.945163	0.803471	1	0.931122
Gross Domestic Product (GDP)	-0.025752	0.742881	0.912965	0.859494	0.931122	1
Average Diesel Price (INR)	-0.031317	0.946816	0.951161	0.97972	0.845571	0.829429
Average Household Electricity Consumption (kwh)	-0.029003	0.746076	0.932728	0.771059	0.997201	0.917378
Total Income of Consumer (INR)	-0.07988	0.036562	0.063845	0.050166	0.083172	0.081473
Age of Consumer	-0.174401	0.024985	0.036467	0.03769	0.038632	0.042355

According to the findings presented in Table 3, a negative correlation is observed between the dependent variable, GEV, and three independent variables, specifically the price of electricity and diesel prices. The remaining independent variables - GDP, per capita income, age of company, population density, average petrol price, average household electricity consumption and vehicle electricity consumption – show positive correlation with the dependent variable. Of these, the correlation of growth of electric vehicles with age of the company (0.157), GDP (0.116), per capita income (0.094) and average household electricity consumption (0.091) was found to be greater than the other variables.

C. Regression Analysis

This study also conducted a regression analysis to further explore the extent to which the independent variables impacted the growth of electric vehicles in India. The findings of a panel quartile regression analysis, in which the researcher divided the panel into quartiles, are presented in Table 4. The findings indicate that six distinct variables make a major contribution to the expansion of electric vehicles within the Indian context.. These are population density (p=0.000), petrol prices (p=0.003), per capita income (p=0.000), GDP (p=0.001), diesel prices (p=0.001) and average household electricity consumption (p=0.0000).

Table 4: Regression Analysis Dependent Variable: TOTAL_INCOME Method: Quantile Regression (Median) Included Observations: 80

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Vehicle Energy Consumption	-1.10E-16	7.39E-16	-0.149313	0.8817
Price Of Electricity Per Unit	-8.61E-13	5.43E-13	-1.583867	0.1177
Population Density	1.45E-13	2.81E-14	5.163503	0
Petrol Prices	2.04E-13	5.38E-14	3.791309	0.0003
Per Capita Income	2.65E-13	3.77E-14	7.03549	0
GDP	-3.99E-15	9.26E-16	-4.303513	0.0001
Diesel Prices	-2.33E-13	5.80E-14	-4.024266	0.0001
Avg Household Electricity Consumption	-6.56E-14	1.17E-14	-5.618049	0
Age Of Company	-2.15E-15	3.63E-15	-0.592382	0.5555
Total Income	1.00E+00	3.67E-19	2.73E+18	0.00E+00
Pseudo R-squared	1.00E+00		Mean dependent var	168905
Adjusted R-squared	1.00E+00		S.D. dependent var	257572.1
S.E. of regression	2.09E-11		Objective	3.12E-10
Quantile dependent var	8.00E+03		Restr. Objective	6678127
Sparsity	6.32E-13			

IV. DISCUSSION

This study's exploration into the drivers of the electric vehicle (EV) sector in India, carried out through the lens of various economic, demographic, and energy-related factors, has revealed relationships and impacts. Firstly, this study indicates that the GEV has a substantial positive correlation with Age of Company, GDP, Per Capita Income and Average Household Electricity Consumption, amongst others. Notably, GDP, per capita income and average household electricity consumption emerged as significantly impactful in the regression analysis, affirming their crucial role in propelling the EV sector forward. This resonates with the findings of Khatua, Kumar, and De (2023, [30]), who established that economic factors in various countries significantly influenced the EV market. Additionally, a noteworthy finding of this research is the negative correlation between GEV and two key variables: Price of Electricity and Diesel Prices. This confirms the work of Higueras-Castillo et al. (2021), who explained that financial considerations, possibly linked with operational costs, are essential in the adoption decision-making process for electric vehicles. Moreover, this study signals that while Average Petrol Price has a positive correlation with GEV, Average Diesel Price inversely relates to it, which can be seen as somewhat counterintuitive and certainly warrants further exploration. Perhaps, as petrol prices rise, consumers are nudged towards considering EVs as a viable alternative, while diesel prices might be affecting the operational costs for companies, thereby impacting their incomes and subsequently, the GEV negatively. Additionally, in India, diesel vehicles have traditionally been seen as more cost-effective compared to petrol vehicles. This might also explain why an inverse relationship is found between diesel prices and growth of electric vehicles. Given the recent decrease in diesel prices, it is plausible that consumers may exhibit a preference for diesel vehicles as a viable substitute for petrol vehicles, potentially surpassing the demand for electric vehicles. Conversely, the importance of Population Density in significantly affecting GEV, as confirmed by the regression analysis in this study, starkly contrasts than the results obtained from prior researches. Chhikara et al. (2021) concentrated more on variables related to consumer perceptions and behaviours in their study of EV adoption, without focusing heavily on demographic aspects like population density. This could suggest a shifting paradigm wherein the demographic composition, especially in a populous country like India, is becoming an increasingly paramount factor in influencing EV growth. Thus, this study provides several points of convergence as well as departure from the existing research about EV adoption and growth. The evident positive correlation between Gross Domestic Product (GDP), Per Capita Income, and the Growth of Electric Vehicles (GEV), aligns with studies like Chhikara et al. (2021), which underscored economic determinants as pivotal in EV adoption. Similarly, the acknowledgment of financial factors, such as electricity and diesel prices, as impactful variables (with a negative correlation) in this study, parallels the findings of Higueras-Castillo et al. (2021). Interestingly, this study identifies Population Density as a significant contributor to GEV brings a novel perspective which is not prominent in prior research such as that by Coffman, Bernstein, and Wee (2017). This could, potentially, highlight a unique characteristic of the EV market in India, reflecting the pervasive impact of demographic factors in a densely populated country, and signals the way for targeted, demographic-centric policies and strategies in the EV sector.

A. Theoretical Implications

This research provides a nuanced understanding of the multiple variables affecting the growth of the EV sector. A new lens through which EV growth could be seen involves not just the direct economic and financial parameters but extends into a broader socio-economic context, where factors like population density assume importance, thus adding to the existing body of research.

B. Practical Implications

The practical implications of this study suggest a two-pronged strategy for policymakers and stakeholders. Firstly, harnessing the positive drivers like GDP, per capita income, and potentially population density, through tailored policies, subsidies, and infrastructural development, could augment the growth of EVs in India. Secondly, the negative correlations, especially pertaining to electricity and diesel prices, highlight the necessity for strategies that safeguard the EV sector from the detrimental effects of these variables, perhaps through additional fiscal measures or alternative energy solutions.

C. Limitations

The primary limitation of this study comes from the dependency on the total income of companies as a proxy for growth of the EV sector, which might not comprehensively capture all dimensions of growth and development of the sector. Furthermore, the study comprises a period of eight years, which, while substantial, may not be reflective of long-term trends and future trajectories, especially considering the rapid evolution of the EV market.

D. Future Research

The scope for further research is ample and essential. Diving deeper into the implications of variables like population density in the Indian context would fortify our understanding of demographic impacts on EV growth. Furthermore, qualitative studies exploring the underlying mechanisms through which economic and financial variables influence both the manufacturers and consumers in the EV domain would add to the empirical findings of this study.

V. CONCLUSION

This study's findings on the complex effects of economic, socioeconomic, and demographic factors on the Indian electric vehicle sector show that this industry is dynamically influenced by a varied factors. This study highlights the need for more research to delve further into the complexities within these correlations and implications, even as it offers unique insights into some demographic variables impacting the rise of EVs in India.

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AUTHOR PROFILE

Swaraj Patil, an adept 12th-grade scholar at Eklavya School Ahmedabad, is a dynamic thinker with a fervent interest in the fusion of economics and computer science. His academic journey is marked by a deep dive into the burgeoning fields of fintech and AI, where he envisions groundbreaking solutions to contemporary challenges. Swaraj's latest scholarly contribution, the paper on "Socio-economic and Demographic Factors Affecting Adoption of Electric Vehicles in India," showcases his analytical prowess and commitment to unraveling complex societal issues. With a keen eye on sustainable technologies, Swaraj aspires to pioneer innovative approaches at the intersection of economic insights and technological advancements, contributing to a future characterized by both sustainability and technological prowess. This paper is a testament to Swaraj's dedication to bridging theoretical knowledge with pragmatic solutions.