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

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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 (EVs) is represented through the proxy of total income of ten prominent Indian EV manufacturing companies for eight years from 2016 to 2023. This analysis is conducted 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. The data for these variables were extracted from governmental and company websites. The study employed statistical methods, including correlation and regression analysis, to examine the relationships between the dependent and independent variables. The results show notable positive correlations with GDP, per capita income, company age, and population density, as well as negative correlations with the prices 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 may help achieve accelerated and sustainable growth for electric vehicles (EVs) in India. This study highlights the unique impact of demographic factors, such as population density, on the electric vehicle (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 global scale has shown a notable trend, marked by visible differences in adoption rates between developed and emerging economies. Established nations, such as Norway, have achieved remarkable market penetration, with electric vehicles (EVs) accounting for an impressive 79% 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 electric vehicles (EVs) comprising approximately 2 per cent of new car sales during the same period.

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One of the many benefits of electric vehicles (EVs) is their tendency to reduce greenhouse gas emissions, which is crucial for mitigating climate change. Additionally, EVs are becoming an increasingly compelling option for environmentally conscious consumers and forward-thinking policymakers due to their ability to reduce dependence on fossil fuels and the potential for lower operational expenses resulting from decreased fuel consumption and reduced maintenance costs. The adoption of electric vehicles (EVs) is influenced by numerous factors, as demonstrated by studies conducted 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 the USA and Europe have pointed to 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 significant 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 cars in different nations over the years. Still, the Indian context has received relatively little attention. This highlights the need for more localised and targeted research in this rapidly 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 electric vehicle (EV) adoption in an emerging economy like India can provide policymakers with invaluable insights, enabling them to formulate targeted strategies that promote the widespread adoption of EVs. This, in turn, can harness the benefits of reduced emissions, energy security, and economic growth, while positioning the nation as a leader in sustainable mobility solutions.

A nuanced understanding of how diverse factors influence electric vehicle (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 organisations to craft effective, context-specific strategies to drive EV adoption and sustainable transportation in the country. To the best of the researcher's knowledge, there is a notable lack of research on 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 the adoption of electric vehicles in India?

The structure of the paper is as follows. The following section presents a comprehensive literature review on electric vehicles and their drivers in India and worldwide. The subsequent section elaborates on the research methodology adopted. The results of the econometric analysis performed utilising data from India are as follows. 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 presents an in-depth literature review of electric vehicles and their drivers worldwide, as well as in India. The following 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 presents the practical implications of the study, its 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 higher efficiency, ranging from 85% to 90%, 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 context of sustainable urban planning, electric vehicles (EVs) are utilised as a means of transportation due to the previously discussed benefits. Numerous proposals have been put forward 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). In recent years, there has been a notable increase in attention to electric vehicles, resulting in a consistent rise in their popularity. Although battery-electric vehicles have experienced significant growth in recent years, it is essential 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 increase in the number of EV producers and the diversity of EV models available on the market. In 1912, the United States had 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]). Electric vehicles (EVs) experienced a resurgence and gained prominence in 2006 (Bakker et al., 2012 [5]), following a period of initial enthusiasm in the 1990s. This year, several notable companies made significant strides towards reintroducing electric vehicles (EVs) to the market. Tesla, for instance, introduced the Roadster, while Mitsubishi unveiled the Colt EV concept. Additionally, major automotive manufacturers such as General Motors (GM), Toyota, and Daimler initiated the development of plug-in hybrid vehicles. Recent studies have shown a rapid growth in electric vehicles (EVs) over the past few years. According to the International Energy Agency's worldwide EV outlook report, global sales of plug-in hybrid electric vehicles and battery-electric vehicles totalled 2.1 million units. The primary obstacles impeding the widespread adoption of electric vehicles are primarily attributed to the high costs associated with battery replacement and the limited 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 significant increase in the 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 goal to achieve a sales volume of over 15 million electric vehicles by 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 during operation. 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 of 2 to 2.5 times compared to internal combustion engines. The decrease in greenhouse gas emissions (GHGs) showed a notable increase as driving behaviour increasingly resembled that of urban driving, notably 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 32% and 46% decrease in CO2 emissions 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, thereby contributing to improved human health.

Additional benefits of electric vehicles include incentives and legislative measures that effectively stimulate and accelerate the adoption of electric cars. Numerous nations worldwide 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 accelerate the adoption of electric vehicles (EVs). 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 subsequent 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 electric vehicle (EV) industry has experienced rapid growth 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, and De (2023) found that, globally, the trends in electric vehicle (EV) sales are encouraging. Chinese producers aim to sell 35% of their electric vehicles (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 electric vehicle (EV) market in the world. The number of electric vehicles (EVs) sold in China reached 2.91 million in 2021, with a current stock of 6.4 million (CBIRI, 2022, [10]). Norway aspires to be a leader in the electric vehicle industry by 2025, when it aims to achieve 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 the provision of financial and non-financial incentives in many countries worldwide, the adoption of electric vehicles remains 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 cars powered by internal combustion engines, their sales have been insignificant. Only 854 electric vehicles (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 electric vehicles (EVs) across different countries underscore the need to identify the various market enablers that support the adoption of EVs.

C. Factors Impacting the 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 consumers must be compelling enough to outweigh the perceived drawbacks 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, EVs are perceived as environmentally benign due to their reduced reliance on petroleum and subsequent decrease in vehicle emissions. The environmental performance of electric vehicles (EVs) has a greater impact on attitudes and intentions to purchase 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 delicate 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 ignite again, necessitating a substantial amount of water to extinguish 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 the price of batteries are essential aspects 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, concerns about hydrogen's potential fossil fuel origins, the difficulty of recharging at home, and safety concerns regarding hydrogen storage are all obstacles to the adoption of Fuel Cell Electric Vehicles (FCEVs) (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 significant 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 electric vehicles (EVs) are adopted. Studies in Australia, Malaysia, Japan, and Russia have shown that individuals with higher incomes, automobile ownership (Lin & Tan, 2017, [36]), and greater education have more in-depth knowledge about and more favourable perceptions of EVs. Age was also found to influence customer preferences for electric vehicles (EVs) in Australia (Ghasri et al., 2019). Compared to younger and older persons, the middle-aged group was more likely to acquire EVs. According to Tiwari et al. (2020, [53]), persons with their cars were more likely to embrace BEVs in the future than persons utilising 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 that population density is related to increased EV sales. Haustein and Jensen (2018, [22]) contrasted traditional and electric vehicle (EV) users to better understand the variables influencing EV adoption in Denmark and Sweden, based on an analysis of sociodemographic data. They found that battery EV users were predominantly male, well-educated, had high salaries, and frequently owned multiple 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 examined the adoption of electric vehicles (EVs) 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 a decrease in price promoted the development of the EV market most effectively. De Gerardo (2019, [15]) confirmed that price was the primary determinant of potential consumers' choice of EVs.

b. Europe

Researchers in Europe found that location, charging infrastructure, sociodemographic characteristics, and psychological factors had a substantial influence on early electric vehicle (EV) adoption. Thogersen and Ebsen (2019, [51]) hypothesised that in Denmark, the leading 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 more inclined to buy an electric vehicle (EV) (Higueras-Castillo et al., 2020).

c. China

Studies in China (Liu et al., 2021) found that vehicle pricing, usage, financial incentives, and convenience factors had a substantial impact on EV adoption. Lin and Wu (2018) found that the two most significant variables influencing the desire to acquire a Battery Electric Vehicle (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 of 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 found to be a less significant driver of electric vehicle (EV) adoption than the construction of charging stations and exemption from purchase 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 the purchase intention of electric vehicles (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) have demonstrated that EV demand and market share can be significantly increased by investing in charging infrastructure and offering incentives to EV users. 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 highlights various technical, environmental, regulatory, and socio-economic factors that affect EV adoption worldwide. In the Indian context, there is a scarcity of research examining the socioeconomic factors that influence the adoption of electric vehicles (EVs). This study, therefore, seeks to identify the socioeconomic factors that influence the adoption of electric cars in India.

III. RESEARCH METHODOLOGY

A. Data

a. Data Sources

This study utilises data on the total income of ten Indian companies manufacturing electric vehicles (both four-wheelers and two-wheelers) in India for the period spanning 2016 to 2023. This data has been taken from the Prowess IQ database. Data related to the 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 sector's growth. 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 explore further 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 significant 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 to operational costs, are essential in the decision-making process for adopting electric vehicles. Moreover, this study indicates that while the Average Petrol Price has a positive correlation with GEV, the Average Diesel Price has an inverse relationship with 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 considered more cost-effective than petrol vehicles. This might also explain why an inverse relationship is found between diesel prices and the growth of electric cars. 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 cars. Conversely, the importance of Population Density in significantly affecting GEV, as confirmed by the regression analysis in this study, starkly contrasts with the results obtained from prior research. 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 (EVs) aligns with studies like Chhikara et al. (2021), which underscore the economic determinants as pivotal in EV adoption. Similarly, the acknowledgement of financial factors, such as electricity and diesel prices, as impactful variables (with a negative correlation) in this study aligns with the findings of Higueras-Castillo et al. (2021). Interestingly, this study identifies Population Density as a significant contributor to GEV, bringing a novel perspective that 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 signal the way for targeted, demographic-centric policies and strategies in the EV sector.

A. Theoretical Implications

This research provides a nuanced understanding of the various factors that influence the growth of the electric vehicle (EV) sector. A new lens through which EV growth can be viewed encompasses not only the direct economic and financial parameters but also extends into a broader socio-economic context, where factors such as population density become important, thereby 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, such as 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 those about electricity and diesel prices, underscore the need for strategies that protect the EV sector from the detrimental effects of these variables, possibly through additional fiscal measures or alternative energy solutions.

C. Limitations

The primary limitation of this study stems from its reliance on the total income of companies as a proxy for the growth of the electric vehicle (EV) sector, which may not comprehensively capture all dimensions of the sector's growth and development. Furthermore, the study spans an eight-year period, which, although substantial, may not accurately reflect long-term trends and future trajectories, particularly given the rapid evolution of the electric vehicle (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 various factors dynamically influence this industry. This study underscores the need for further research to investigate the intricacies of these correlations and their implications, while also providing valuable insights into specific demographic variables that contribute to the growth of electric vehicles (EVs) in India.

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