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# A CROSS-SECTIONAL STUDY OF FACTORS INFLUENCING PURCHASING CARS IN EUROPEAN UNION – DOES THE ELECTRIC AND HYBRID CARS CHANGE THE CONTEMPORARY BUSINESS APPROACH?

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**Abstract.** This study aims to examine the expansion of the electric vehicle fleet in the context of transport electrification in the European Union. We assessed the car market, following demand and sales trends for electric and hybrid cars. It was explored the possibility of a causal relationship among the percentage of BEV + PHEV in the total fleet and purchasing power, loading infrastructure, government support, the level of education and the degree of digitalization. To achieve the main objectives of the research to assess the existence and magnitude of the causal effects of the considered variables on the percentage of BEV + PHEV in the total fleet, we conducted a cross-sectional analysis in 2020 among the European Union (EU) countries. Five research hypotheses were formulated and tested. The results confirmed that the economic and social development of a region, the charging infrastructure, the government support measures, and the degree of digitalization positively influence the desire of the EU population to buy electric cars.

**Keywords:** digitalization, environment, battery electric vehicles, plug-in hybrid electric vehicles, sustainability, consumer attitudes.

**JEL Classification:** D24, E24, O13, Q1.

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## 1. Introduction

In modern economies, the transport sector has undergone a significant transformation in recent years with the rise of electric and hybrid cars. As consumers become increasingly aware of the environmental impact of their purchasing decisions, the demand for electric and hybrid vehicles has grown significantly. This shift in consumer preferences has led to a transformation of the transport sector, with traditional fossil fuel-powered vehicles being replaced by cleaner, more sustainable alternatives. To address these major challenges in the economies, sustainable transportation systems have become increasingly important and electric and hybrid cars are an important component of this movement towards sustainability (Rehman et al., 2023; Zhang et al., 2024). As literature highlights (Dominković et al., 2018; Heal, 2022) the driving force behind the transition from fossil fuels is the pressing need to limit the climate change and, electrification offers the advantage of improved energy efficiency, as electric motors are more efficient than internal combustion engines (ICEs), with the amendment that the energy efficiency alone doesn't always lead to lower greenhouse gas (GHG) emissions, unless the electricity grid is powered by clean energy. A number of studies have examined various aspects of this transition in decarbonisation and GES limitation, including the environmental impact of electric powertrains in comparison to conventional ones (Koroma et al., 2023), energy management strategies for hybrid electric vehicles (Azim Mohseni et al., 2024), and the integration of fuel cell-enabled hybrid energy storage systems in electric vehicles (Shekhawat & Bansal, 2023). Taylor (2021) addressed key challenges related to energy efficiency, emissions, tribology, and fluid requirements in the design of electrified passenger vehicles, underscoring the importance of these factors in optimizing vehicle performance and sustainability. Mustafa et al. (2021) examined the influence of environmental awareness on electric vehicle adoption, proposing a mixed-method approach to better understand consumer decision-making processes in the context of electric vehicle adoption. Ziółkowski et al. (2023) conducted empirical measurements of energy consumption and exhaust emissions across hybrid, conventional, and electric vehicles with range extenders, providing critical insights into the environmental performance of different powertrain technologies.

As Bunsen et al. (2018) and Crabtree (2019) argue, although road transport vehicles are responsible for about 94% of emissions in the transport sector and electrification has emerged as a most significant technological advancement decarbonize the sector. Based on current literature (Aijaz & Ahmad, 2022) it is evident that while the implementation of EVs is crucial to reducing carbon emissions in road transport, relying solely on electrification will not be adequate to achieve complete decarbonisation by 2050. Despite the presence of other factors that could expedite the decarbonisation of transport (Di Felice et al., 2021; Hossain et al., 2022; Arat et al., 2022), current policies tend to prioritize the rapid adoption of EVs (Electric Vehicles) while neglecting these variables. Furthermore, there are studies (Mofolasayo, 2023; Ayadi et al., 2019) which indicate that solely transitioning to electric-powered transport may not be enough to achieve the desired climate targets. To meet the current pressures of the energy market, until 2030, the existing distribution networks will have to expand to serve additional loads by installing renewable energy production systems to cope with the increased demand for electricity.

In the context of the energy crisis, it is interesting to study battery-powered electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) market acceptance. Today's society faces multiple problems in the energy auto market. Thus, on the one hand, there are restrictions imposed by climate change and the decrease in access to resources, which has led to significant increases in the prices of fossil fuels. On the other hand, some studies (Zhou et al., 2015) showed that, despite the benefits offered, the use of electric and hybrid vehicles in many countries still needs to be improved.

Electric and hybrid cars are becoming increasingly popular as consumers seek to reduce their environmental impact and save money on fuel costs. There has been a growing trend in electric and hybrid cars purchasing modeling to enhance the representation of consumer behavior and increase its realism. This has led to the development of various approaches and techniques aimed at better capturing the complex interplay between contemporary business patterns and consumer decision-making processes. As a result, there has been a growing interest in modelling the purchasing behavior of consumers when it comes to these types of vehicles. However, to our knowledge, relatively research studies have investigated the decision to purchase electric or hybrid vehicles. Most studies (Febransyah, 2021; Huang & Ge, 2019) focus on the approach from the perspective of consumer behaviour, while our research considers a path from the perspective of market characteristics. According to Hamilton et al. (2020), sales of electric cars will increase by almost 30% annually over the next ten years, so that by the end of the decade, one in three new cars sold globally will be electric.

The European Environment Agreement targets reducing transport-related greenhouse gas emissions by 90% by 2050 through the Sustainable and Smart Mobility Strategy initiative (European Comission, 2020). With regard to road transport, the provisions included in this document on ensuring the sustainability of transport are intended to stimulate the adoption of zero-emission vehicles using renewable fuels and to ensure the related infrastructure, including, among other things, the installation of 3 million public charging points by 2030, but also providing incentives for users.

The emergence of hybrid-electric cars has been driven by a combination of factors, including environmental concerns, advances in technology, and government policies aimed at promoting the adoption of cleaner vehicles. In this context, the electric and hybrid cars have been perceived as potential instruments in achieving the goals of promoting sustainable transportation in contemporary economies. This type of transportation vehicles presents both advantages and disadvantages, which are prior be consider and understand before acknowledging the intrinsic effects of promoting such instruments.

Electric and hybrid vehicles (EHVs) are a step towards a sustainable mobility system. Several features of electric vehicles support their use in a green transportation system. Thus, electromobility is the cheapest solution for decarbonizing transportation, and electric cars can efficiently contribute to the transition to 100% renewable energy and in addition, zero toxic exhaust emissions ensure less polluted air, and batteries can be part of a circular economy.

We intended to investigate the decision to purchase an electric or hybrid vehicle from the perspective of the consumer value theory. Accordingly, consumers are all the more likely to make purchase decisions because the products contain specific values and meet their requirements (Sheth et al., 1991). From this perspective, EHVs, in addition to satisfying the daily needs of travel consumers, also support government efforts to reduce the carbon footprint and protect the natural environment.

Among the factors studied in the present article, the total number of public charging points and governmental incentives and legislation are also found in the results of numerous studies (Potoglou & Kanaroglou, 2007; Ninh et al., 2014). These factors, along with the purchase price and technical attributes – autonomy, charging time, and performance – significantly influence the purchase of electric or hybrid vehicles (Heffner et al., 2007; Hess et al., 2012; Valeri & Danielis, 2015; Adhikari et al., 2020). In this sense, the involvement of governments is essential, both through stimulating legislation and infrastructure development. Also, an important role belongs to the producers. They must have in view the development of the most efficient technologies to both reduce the cost and increase range at the same time.

Our findings highlighted the fact that local conditions can influence purchase decisions, and these influences are not yet well clarified in the literature. The study of these specific factors could represent a research direction in the future. It is worth mentioning that consumers often show reluctant attitudes towards BEVs and HPEVPHEVs. This analysis, like many other studies, shows that the relatively high price combined with the conditions of reduced purchasing power can be an important cause of this attitude, confirming the statements of (Tu & Yang, 2019). Furthermore, a lag model could offer a response to verify this result.

The novelty of this paper consists in the fact that employs a unique methodology to provide an overview of the factors that may influence the decision to purchase electric and hybrid cars in the European Union. The findings of this study offer valuable insights for further research aimed at decarbonizing the transportation sector, particularly in the areas where the interests of consumers and policymakers intersect. Also, this study delves deeper than previous literature by not only shedding light on the advantages and disadvantages of market characteristics concepts in relation to the purchase of electric and hybrid cars, as well as mobility behaviour, but also offers practical and easy-to-implement recommendations on incorporating diverse perspectives on consumer behaviour, supported by five research hypotheses.

Additionally, several studies suggest that one of the primary trends in electric and hybrid car purchasing modelling is the incorporation of psychological and social factors. Summarizing the literature survey, it could be remarked that electric and hybrid cars are becoming increasingly popular, and there is a growing interest in modelling consumer behaviour when it comes to purchasing these vehicles. The main trends in electric and hybrid car purchasing modelling include the incorporation of psychological and social factors, the use of advanced analytical techniques, the consideration of policy interventions, and the incorporation of environmental considerations. These lines are all aimed at providing a more accurate representation of consumer behaviour and helping policymakers and businesses make informed decisions about the future of the electric and hybrid car industry. This study aims to fill, at least partially, this gap.

The research paper argument is structured as follows: after the introductory and literature review section, it continues with Section 2 which presents the materials and methods employed in the research. In dedicated subsections are described the data, research purpose and hypotheses and the research methodology applied. Section 3 details the results and discussion which content the main findings highlighted during the investigation carried out and an extended analysis of the implications and interactions resulted during the research. Finally, the last sections are dedicated to conclusions and policy implications. Also, limits and further directions for further researches are highlighted.

## 2. Literature review

A review of the existing literature on electric and hybrid car consumer choices and preferences reveals that previous studies that have presented sets of measures have mostly analysed the literature in a non-systematic manner concentrated on consumer behaviour and not from the perspective of market characteristics. This highlights the need for more comprehensive and systematic approaches to analyzing and synthesizing the available research on this actual topic

Until 2020, 17 barriers against the spread of electric vehicles have been identified in the literature (Adhikari et al., 2020), classified into five categories: technical, political, economic, infrastructure and social. Studies have shown that consumers consider the first four categories to be more important in the purchase model than social barriers. Thus, the lack of charging stations, the higher purchase price of electric vehicles compared to classic ones, poor government policies, difficult maintenance due to the weak network of workshops, and short battery life are the most often cited reasons that inhibit the purchase of an electric vehicle. Regarding infrastructure, the literature (Ninh et al., 2014) shows that political decision-makers and electric vehicle manufacturers should collaborate for its development.

Despite all these shortcomings, the objective of reducing CO2 emissions requires the decarbonization of transport energy. In this sense, Agarwal and Alam (2018) shows that BEVs are the most attractive option from the point of view of the Well-to-Wheel CO2 emission factor. In terms of price, PHEVs are a more affordable alternative. Despite all these shortcomings, the objective of reducing CO2 emissions requires the decarbonization of transport energy. In this sense, Agarwal shows that BEVs are the most attractive option from the point of view of the Well-to-Wheel CO2 emission factor. In terms of price, PHEVs are a more affordable alternative.

Regarding the prices of electric or even hybrid vehicles, since 2007, Heffner et al. showed that these would continue to represent a major concern for customers until 2030 when they estimated that a sufficient degree of learning would be achieved to allow sunk costs to decrease sufficiently to ensure reasonable payback periods.

In the literature, numerous studies have analyzed the impact of different variables that influence consumer preference for electric vehicles. Buhmann and Criado (2023) identified three categories of factors, namely (1) sociodemographic factors, (2) machine attributes and (3) environmental aspects. Regarding sociodemographic variables, they studied the role of reputation, status and image in consumer preferences for electric vehicles. Thus, they showed that reputation and status lead consumers to prefer electric vehicles. However, there are studies (Rahmani & Loureiro, 2019) that claim that consumers buy electric vehicles more for reasons of reputation and status than for environmental reasons, following a politically correct behaviour from a social point of view. This opinion is consistent with the results of the study by Dutta and Hwang (2021), which shows that the subjective norm positively influences consumers' intention to buy electric vehicles. Thus, the social environment and the influence of the mass media represent strong factors for stimulating purchasing behaviour.

Their results are in agreement with other research (Olson, 2013; Mukherjee & Ryan, 2020; Bjerkan et al., 2016; Zhang et al., 2011; Ozaki, 2011). More recent studies (Christidis & Focas, 2019) show that the inclination to purchase an electric vehicle or electric plug-in hybrid varies directly with income, and level of education, manifesting itself more strongly in the urban environment. Thus, the declared intention to purchase a hybrid or electric vehicle shortly increased by over 5% in 2018 compared to 2014. At the same time, there are significant differences between countries, but also between customer segments. This variability suggests the need to take into account, in addition to the classic factors, social, economic, behavioural, and local conditions. In this sense, in the opinion of Christidis and Focas (2019), mobility needs and government support measures adapted to specific needs at the local level must be taken into account. In our opinion, national culture can also influence buying and consumption behaviour. Although important progress has been made in reducing disparities between EU Member States, differences continue to exist, both economically and socially. These differences are also visible in the field of innovation and digitalization, as well as consumer behavioural models. Gómez Vilchez et al. (2020) explored the adoption of battery electric and plug-in hybrid electric powertrains in key electro-mobility markets using system dynamics modeling, offering insights into market trends and potential barriers. Choi et al. (2020) applied a well-to-wheel (WTW) analysis to predict greenhouse gas emissions across various vehicle types, including internal combustion engine vehicles (ICEVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs), providing a comparative environmental assessment. In another study, Turkdogan (2021) designed a renewable-based hybrid energy system tailored for residential electrical loads and fuel cell electric vehicles, emphasizing the need for zero greenhouse gas emissions in future energy systems. Wang et al. (2020) examined the application of low-global warming potential (GWP) refrigerants in solar-driven ejector-compression hybrid refrigeration systems, highlighting the potential for environmentally friendly cooling technologies. Harris et al. (2020) developed a probabilistic framework for fleet analysis, evaluating energy consumption, life cycle costs, and greenhouse gas emissions associated with different bus technologies, offering a comprehensive approach to assessing transportation sustainability. Balestra and Schjølberg (2021) introduced a simulation tool for evaluating zero-emission hybrid power plants in marine applications, showcasing the potential for integrating fuel cells and batteries to reduce emissions in the maritime sector. Turoń et al. (2022) focused on optimizing vehicle selection for car-sharing systems, considering environmental impact and operational efficiency to identify the best-suited vehicles for sustainable urban mobility.

This opinion is in line with the results of the study by Huang and Ge (2019) which shows that there are significant differences in terms of consumers' intentions to buy electric vehicles. At the same time, they show that attitude, perceived behavioural control, cognitive status, product perception and monetary stimulus policy measures have significant positive effects on purchase intentions. It should be noted that subjective norms and policy measures of non-monetary incentives do not have a significant impact on purchase intention. These opinions are consistent with the results from the innovation diffusion perspective. Thus, Jansson et al. (2017) showed the important role of several weak social ties, such as neighbours, in contrast to a lower level of perceived interpersonal influence in the case of strong social ties, such as family and colleagues.

## 3. Materials and methods

In this study, we conducted a cross-sectional analysis of 2020 between EU countries. We have analysed the percentage of BEV + PHEV in the total fleet as a dependent variable. As causal variables, we considered the purchasing power, the charging infrastructure, the support provided by governments, the level of education and the degree of digitalization. We have evaluated the purchasing power as Actual individual consumption (AIC). Data were collected from Eurostat (PRC_PPP_IND_custom_1039745). The charging infrastructure was evaluated according to the total number of normal and fast public charging points, the data being collected from The European Alternative Fuels Observatory (EAFO). The government support has been assessed as a number of support measures that a government provides to the population for the purchase of electric vehicles.

The digital transformation of society contributes to economic and social growth and environmental sustainability, with technology and innovation representing sources of advantages and benefits for sustainable development (Mondejar et al., 2021). The development of intelligent systems connected to the Internet of Things, and innovative technologies, designed as game-changing tools bring benefits to the automotive industry sector: clean energy production, sustainable production practices, reducing emissions. These considerations led us to consider the degree of digitization as a variable of interest in our study. We used the Digital Economy and Society Index (DESI) to measure digitalization.

There are some studies (Febransyah, 2021) that claim that electric vehicles are more acceptable among highly educated consumers. Also, Huang and Ge (2019) show that segments with a high level of education show a positive attitude towards the intention to purchase electric vehicles. There is evidence in the literature that people with higher education are more concerned about the environment (Jansson et al., 2017). This could partially explain this type of behaviour. On the other hand, a higher level of education generates higher incomes, which allows them to pay the price of electric vehicles, which is higher than that of classic ones. At the same time, there are studies that state the opposite (Hackbarth & Madlener, 2016). Thus, we considered studying whether the education level positively influences the desire of the EU population to buy electric or hybrid cars. To measure the level of education we used the education index, as the education dimension of the Human Development Index (HDI), which is an average of mean years of schooling (of adults) and expected years of schooling (of children), both expressed as an index obtained by scaling with the corresponding maxima. For 2020, the values of the beginning of education were estimated using the forecast function.

Based on the data presented above, our research aimed to highlight a causal relationship between the percentage of BEV + PHEV in the total fleet and purchasing power, loading infrastructure, government support, the level of education and the degree of digitalization.

Considering the above reasoning, as well as the scientific research aims proposed, the following hypotheses describe the integrated analysis model developed to highlight the factors influencing purchasing electric and hybrid cars in European Union under different determinant conditions:

*Hypothesis 1 (H1). The economic and social development of a region positively influences the willingness of the EU population to buy electric or hybrid cars.*

*Hypothesis 2 (H2). The charging infrastructure positively influences the consent of the EU population to buy electric or hybrid cars.*

**Table 1.** Variables definitions and data sources for key parameters covered by the study (source: author's own selection)

| Variables | Definitions | Sources |
|---|---|---|
| Perc_ BEV+PHEV | Percentage of BEV+PHV for passengers in the total fleet | European Alternative Fuels Observatory (https://www.eafo.eu/countries/european-union/23640/vehicles-and-fleet) |
| AIC | Actual individual consumption expressed as Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates | Eurostat (PRC_PPP_IND__custom_1039745) |
| Pb_Ch_Points | Total number of normal and fast public charging points | European Alternative Fuels Observatory (https://www.eafo.eu/countries/european-union/23640/infrastructure/electricity) |
| Incent_Leg_ PEV | Incentives and Legislation for PEV for 2020 | European Alternative Fuels Observatory (https://www.eafo.eu/countries/european-union/23640/incentives) |
| DESI | The Digital Economy and Society Index | https://digital-strategy.ec.europa.eu/en/policies/desi |
| Ed | Education Index | HDRO calculations based on expected years of schooling and mean years of schooling from UNESCO Institute for Statistics (2020) and other sources. (http://hdr.undp.org/en/indicators/103706#) |

*Hypothesis 3 (H3). The government support positively influences the consent of the EU population to buy electric or hybrid cars.*

*Hypothesis 4 (H4). The level of education positively influences the consent of the EU population to buy electric or hybrid cars.*

*Hypothesis 5 (H5). The degree of digitalization positively influences the consent of the EU population to buy electric or hybrid cars.*

To assess the existence and magnitude of the causal effects of the considered variables on the percentage of BEV + PHEV in the total fleet, we chose to use the cross-sectional analysis for the data available in 2020 for the EU Member States.

Although the beginning was timid, under the pressure of environmental movements, the evolution of sales of electric cars has grown rapidly over the past decade. In 2020, global car sales fell by more than 15% due to the pandemic. However, registrations of electric cars increased by over 40%. About 3 million electric cars were sold globally, accounting for almost 5% of total sales, with Europe surpassing China for the first time, considered the world's largest electric vehicle (EV) market. This evolution in jumps, characteristic, moreover, of any beginning period, supports the use of cross-sectional regression.

## 4. Results

The aim of the present study is to examine the expansion of the electric vehicle fleet in the context of transport electrification in the European Union. Consequently, for this study, we focused on the number of electric passenger cars in the EU. In 2020, the electrically charged segment (battery-powered hybrid electric vehicles and plug-ins) significantly increased its market share (Figure 1). This increase must also be correlated with the general decrease in new passenger car registrations caused by the COVID-19 epidemic.

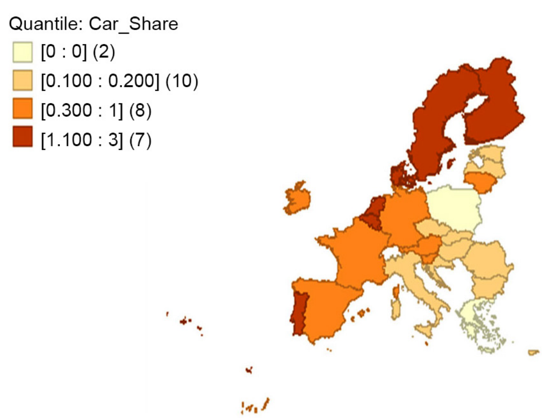
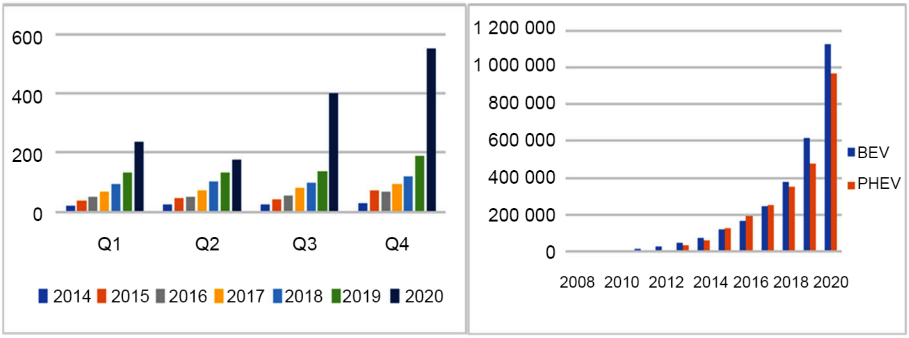



**Figure 1.** Share of EVs in total passenger vehicle fleet (%), EU-27 and UK
(source: authors' own computations based on data in Table 1)

Demand for electric cars is growing exponentially due to rising environmental concerns across society. The car market analysis (Figure 2) shows that electric and hybrid vehicles are gaining more and more popularity due to these advantages.




a) b)

**Figure 2.** Market research about EV sales: a – Quarterly sales volume of BEVs and PHEVs in Europe from Q1 2014 to Q2 2020 (in 1,000s); b – Volume sales of BEVs and PHEVs in Europe about EV sales in European Union (source: authors own computations based on data in Table 1)

After a timid start, during 2012–2020, the electrically-chargeable cars (BEV+PHEV) market increased almost tenfold, from 57942 units to 5282604, according to EAFO (Figure 3). Notable increases in the market for alternative fuel vehicles have started to be evident since 2014 when sales of electric cars have practically doubled.

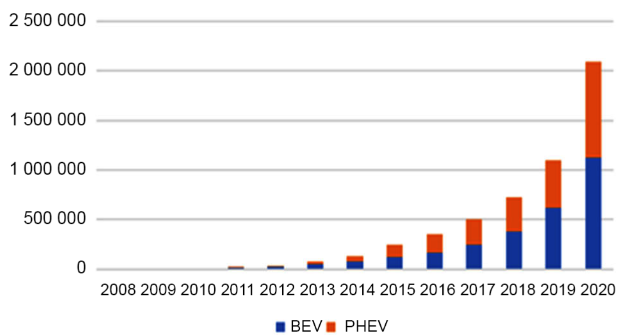



**Figure 3.** Trends over time in the EU (2008–2020, in units) (source: authors' own computations based on data in Table 1)

Furthermore, in 2020, fossil fuel cars dominated EU car sales, covering a market share of 75.5%. The remaining almost a quarter of all cars sold were powered alternately, of which electrically charged cars accounted for 10.5%. This value means a tripling compared to the previous year. Battery-powered electric vehicles accounted for 5.4% of total new car sales, with plug-in hybrids at 5.1%. Thus, in total, the market for electrically charged cars has grown by 10.0 percentage points in the last seven years. BEVs slightly exceeded PHEVs, the former registering an increase of 5.1 percentage points and the latter by 4.9 points. During the same period, the market share of hybrid electric vehicles increased by 10.5 percentage points, representing in 2020 more than half of the market for "electrified" cars. Less than 1% of all cars sold in 2020 are those powered by natural gas (0.6%), this category registering a decrease of 0.4 percentage points compared to 2014 (ACEA, 2021).

According to the data summarized in the ACEA report, only four countries register almost three-quarters of the electric cars that are sold in the EU. These have among the highest values of GDP. Thus, the top five countries in terms of EU EV market share are as follows: 1. Sweden – 32.2% (GDP of € 45,610); 2. Netherlands – 25.0% (GDP of € 45,790); 3. Finland – 18.1% (GDP of € 42,940) and 4. Denmark – 16.4% (GDP of € 53,470). Cyprus, Lithuania, Estonia, Croatia, and Poland are at the opposite pole, each with market shares below 2%. This distribution shows a clear gap in the accessibility of ECVs between Central and Eastern Europe and Western Europe and a pronounced north-south gap across the EU. Analysing the availability of infrastructure in the EU, it is found that it has developed continuously, the starting point being also in 2014. Thus from 26391 charging points, it reached 224237, the increase being 750%. However, the number is far below what is needed. Of the total charging points available today in the European Union, about 70% are located in the Netherlands, France and Germany. The country with the weakest infrastructure is Cyprus, with 70 charging points.

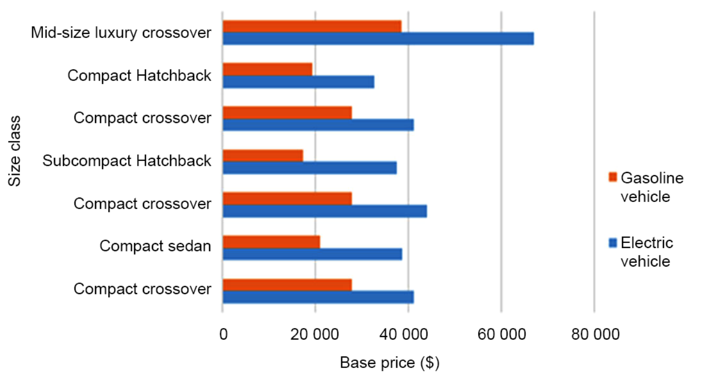



**Figure 4.** Base-price of top-selling EVs versus base-price of highly rated gasoline-powered vehicle in the same size class (source: authors' own computations based on manufacturer's suggested retail price (White, 2022))

Regarding the initial purchase cost, this is the main concern of potential buyers from Europe and other continents. Figure 4 summarizes the 2021 sales results for the top-selling electric vehicles in the US market compared to the top-rated and best-selling gasoline vehicles in the same size class. Figure 4 shows that electric cars are significantly more expensive in every category. However, some studies show that electric cars are relatively inexpensive compared to conventional ones if taxes and maintenance costs are considered (Christidis & Focas, 2019).

## 4.1. Descriptive statistics and correlation analysis

Table 2 summarizes the selected variables. It was remarked significant disparities between the selected samples, revealed by the large standard deviation, in terms of Pb_Ch_Points. Unfortunately, we notice that there are states like Estonia, Poland and Slovenia where governments do not seem interested in supporting electric cars, where there are no incentives. But also, there are highly involved governments, such as Austria and Sweden, with Incent_Leg_PEV values of five, which means the existence of five types of support measures.

The average purchasing power is 93.4%, below the reference threshold of 100 set as an average in the European Union. In addition, in terms of the average value of the percentage of BEV + PHV for passengers in the total fleet (0.84%), it should be noted that only eleven countries – all belonging to the category of developed economies – are above it, i.e. just over a third of the number of EU member states.

**Table 2.** Summary statistics of the variables (source: author's own selection)

| | Perc_BEV + PHEV | AIC | Pb_Ch_Points | Incent_Leg_PEV | DESI | Ed |
|---|---|---|---|---|---|---|
| Mean | 0.844815 | 93.37037 | 7770 | 2.555556 | 53.47844 | 0.864348 |
| Standard Error | 0.170471 | 3.74628 | 2975.863 | 0.293972 | 1.894678 | 0.010207 |
| Standard Deviation | 0.885795 | 19.46624 | 15463.04 | 1.527525 | 9.845035 | 0.053037 |
| Sample Variance | 0.784634 | 378.9345 | 239105569 | 2.333333 | 96.92472 | 0.002813 |
| Kurtosis | 0.646815 | –1.065654 | 8.6173 | –0.87824 | –0.64596 | –1.22901 |
| Skewness | 1.19215 | 0.269926 | 2.9089 | –0.07856 | 0.202428 | –0.13127 |
| Minimum | 0.05 | 61 | 70 | 0 | 36.43707 | 0.764121 |
| Maximum | 3.18 | 131 | 66665 | 5 | 72.3128 | 0.945411 |
| Confidence Level (95%) | 0.350409 | 7.700588 | 6116.9744 | 0.604269 | 3.894566 | 0.020981 |

Further, Table 3 reveals the correlations between the variables. The strong linear relationships in which the correlation coefficient is over 0.7 must be considered to prevent the statistical phenomenon of multicollinearity. According to Field et al. (2012), we considered taking the variables mentioned above into separate regression estimates to obtain a high level of significance in the regression model.

**Table 3.** The correlation matrix (source: author's own selection)

| | Perc_BEV + PHEVPHEV | AIC | No_Pb_Ch | Incent_Leg_PEV | DESI | Ed |
|---|---|---|---|---|---|---|
| Perc_BEV + PHEVPHEV | 1 | | | | | |
| AIC | 0.788904 | 1 | | | | |
| Pb_Ch_Points | 0.581867 | 0.501973 | 1 | | | |
| Incent_Leg_PEV | 0.559915 | 0.409311 | 0.328084 | 1 | | |
| DESI | 0.763727 | 0.637375 | 0.30842 | 0.309429 | 1 | |
| Ed | 0.464139 | 0.461549 | 0.316363 | –0.01414 | 0.686013 | 1 |

In all analysed cases, in the scatter plot (Figure 5), the slope of the curve has a positive value, which means that the percentage of BEV + PHEVPHEV for passengers in the total fleet is the higher in a country as the purchasing power or loading infrastructure or support measures, respectively, the degree of digitalization in that country are higher. The best match is in the case of purchasing power. This variable explains in a proportion of over 62% the variation of the percentage of electric vehicles. A similar ratio is visible in the case of digitalization, respectively over 58%.

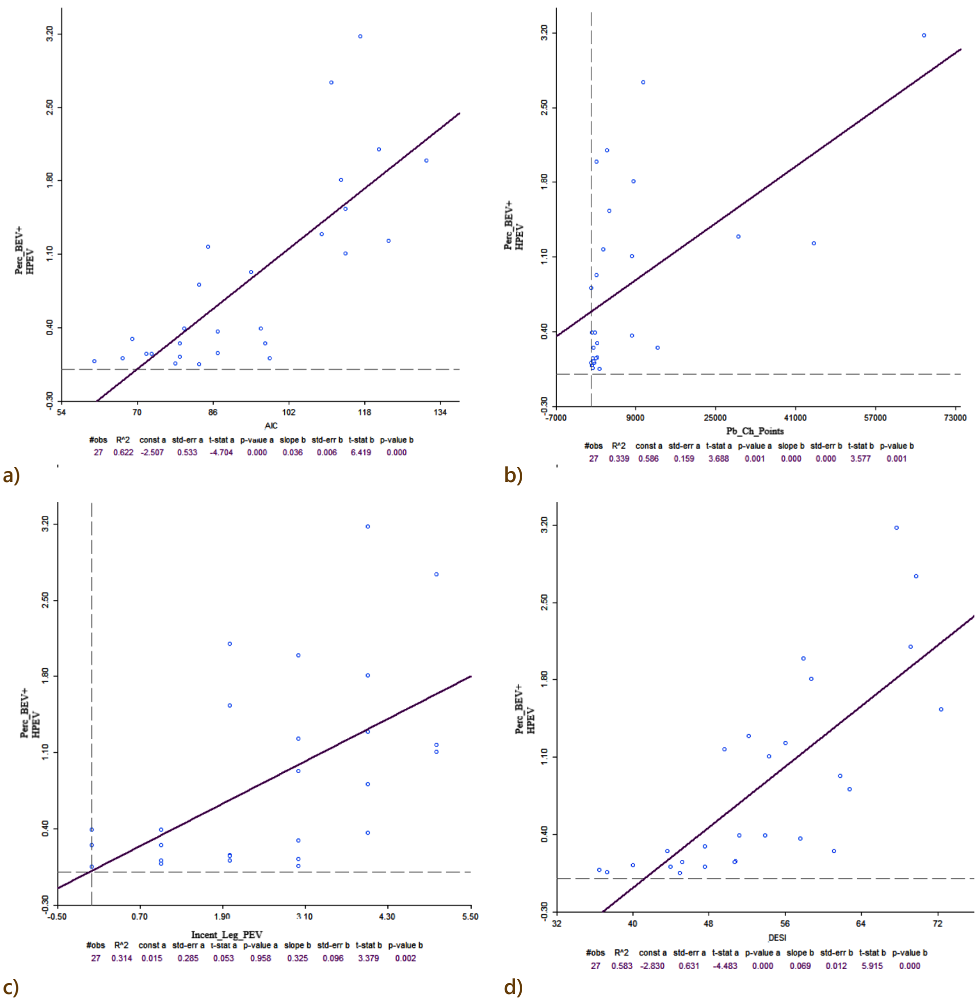



**Figure 5.** Assessment of the linear relationship between variables: a – Variance of the percentage of BEV + PHV for passengers in the total fleet explained by the variance of AIC; b – Variance of the percentage of BEV + PHV for passengers in the total fleet explained by the variance of Pb_Ch_Points; c – Variance of the percentage of BEV + PHV for passengers in the total fleet explained by the variance of Incent_Leg_PEV; d – Variance of the percentage of BEV + PHV passenger cars in the total fleet explained by the variance of DESI (source: authors' own computations based on data in Table 1)

We tested multicollinearity because we observed average correlations among some of the explanatory variables (see Appendix, Table A1). As the variance inflation factor (VIF) value is less than 10, we can conclude that no severe multicollinearity exists in the model (Hair et al., 2010).

To test the serial correlation, we performed a Breusch-Godfrey Serial Correlation test. According to the test results, the p-value is 29% (see Appendix, Table A2). As this value is much more than 5%, we cannot reject the null hypothesis that the residual is not serially correlated, which means that this model has no serial correlations. To test the heteroskedasticity of regression errors, we used the Breusch-Pagan-Godfrey test. The test results presented in Appendix, Table A3 show a p-value of 58.55%, much higher than 5%. This result means we cannot reject the null hypothesis: the residual is not heteroscedastic, meaning that the residual is homoscedastic.

Residual normality testing was performed using the Jarque-Bera test. The test value is 0.40 and the p-value is 82% > 5% (see Appendix, Figure A1). These results support the acceptance of the test's null hypothesis, namely that the residues are normally distributed.

## 5. Discussions

The purpose of the regression analysis was to determine the significance and confirm all selected factors' statistical importance. The five factors were used as five independent variables. Of these, the coefficient of the education index is not statistically significant at a 95% confidence level. This result is consistent with Febransyah's study (2021), which showed that highly educated consumers have a moderate preference for purchasing BEVs. Thus, we considered a linear regression model, in which the percentage of BEV + PHEV for passengers in the total fleet (Perc_BEV + PHEV) was used as a dependent variable. The independent variables are: (1) purchasing power (AIC), (2) loading infrastructure (Pb_Ch_Points), (3) supportive government measures (Incent_Leg_PEV) and (4) the degree of digitalization (DESI). The summarizing of the regression analysis is presented in Table 4. The high values of the coefficient of determination (R2) and the low standard error prove the significance of the regression performed.

**Table 4.** Summarizing regression model (source: author's own selection)

| R | R Squared Adjusted | R Squared | Standard Error of the Estimate |
|---|---|---|---|
| 0.909786[a] | 0.796386 | 0.827711 | 0.399703 |
| a: Predictor is a constant | | | |

The regression coefficients obtained are presented in Table 5. It should be noted that all four factors are statistically significant. This result entitles us to say that we can accept this model for further analysis in certain countries and groups of countries.

**Table 5.** The Coefficients of the variables of the regression analysis (source: author's own selection)

| Variable | Coefficient | Std.Error | t-Statistic | Probability |
|---|---|---|---|---|
| CONSTANT | –2.97515 | 0.484039 | –6.14651 | 0.00000 |
| AIC | 0.0143561 | 0.00587658 | 2.44294 | 0.02306 |
| Pb_Ch_Points | 0.0000124 | 0.00005936 | 2.10059 | 0.04736 |
| Incent_Leg_PEV | 0.132134 | 0.0570868 | 2.31462 | 0.03035 |
| DESI | 0.0382391 | 0.010362 | 3.69032 | 0.00128 |

Regression model may be created in accordance with data shown in Table 5:

$$Perc\_BEV\_HPEV = -2.975147 + 0.014356 \times AIC + 0.0000012 \times PB\_Ch\_Points + 0.132134 \times Incent\_Leg\_PEV + 0.038239 \times DESI. \quad (1)$$

Following the analysis, we identified the positive influence on the evolution of the percentage of BEV + PHEV for passengers in the total fleet for the economic factors represented purchasing power (AIC) and research hypothesis (H1) presented above. One possible explanation would be that a country's more efficient economic development is also reflected in its citizens' purchasing and consuming behaviour. Some authors (Ivașcu et al., 2020) show that developed countries has a developed affinity for electric cars precisely because their gross domestic product is well above the European average. The results regarding the effect of socio-economic and socio-demographic variables are contradictory, a situation that can be found in many studies (Zhang et al., 2011; Ozaki, 2011; Olson, 2013; Bjerkan et al., 2016; Rahmani & Loureiro, 2019; Mukherjee & Ryan, 2020; Buhmann & Criado, 2023).

Another issue influencing the willingness of the EU population to buy electric cars is the number of charging points that complement the specific infrastructure. The increase in sales of electric vehicles will create high demand in the development of charging stations, as confirmed by studies (Pal et al., 2021). The increasing degree of integration of electric vehicles has motivated many efforts. These efforts focus on two aspects. The first one refers to the impact associated with heavy load on the electricity grid. The second concerns the consequences for the EV users, who consider the quality of service to be determined by competition regarding charging resources, including charging points and power supply. Thus, the lack of charging infrastructure remains the main barrier to the adoption of electric vehicles. Our results are in line with the conclusions of other studies (Dutta & Hwang, 2021) showing that the difficulty of loading, determined by the long loading time and insufficient loading infrastructures, has potentially negatively influenced the intention to adopt. Moreover, some authors have shown that consumers are less interested in public charging stations but they are more willing to charge electric vehicles at home (Adhikari et al., 2020). Overall, however, it is shown that charging facilities in both public and domestic areas intensify the intention to adopt consumers. All these results confirm our second hypothesis (H2).

EU governments seem to have understood the role of financial incentives in convincing consumers to buy electric vehicles. The results of our analysis confirm the conclusions of previous studies (Xue et al., 2021), which showed that financial incentives positively influence the favourable attitude of consumers of electric vehicles in EU countries. Moreover, some researchers (Whitehead et al., 2019) have pointed out that government incentives such as economic subsidies, fiscal incentives, preferential lending policies, and facilities development can significantly encourage young consumers in the millennial generation to develop green purchasing and consuming habits. To demonstrate this, we aim to conduct future research that takes into account a lag model. Given these results, we can also consider that government incentives for the purchase and use of an electric or plug-in car have a positive link with the favourable attitude of the population towards the purchase of this type of car. Thus, the third hypothesis (H3) is also confirmed.

Regarding the fourth hypothesis, about the influence of the level of education on the consent of the EU population to buy electric cars, the coefficient of this term was not statistically significant. We can therefore say that the H4 hypothesis is not confirmed. Thus, we preferred the regression model using only the other four variables, as presented in Table 5. Consideration of the level of education was based on previous studies (Liao et al., 2017) that showed that public welfare affects the population and determines leadership behaviour and the need for transport, which in turn affects the market. These studies considered the social dimension in assessing the pattern of consumer behaviour, identifying two main interactions:

public welfare and employment. For estimating public welfare, also HDI was used, which reports life expectancy, income and level of social education.

Our results show that there is still a significant variability between EU member states regarding the purchase of BEVs or PHEVs, which remains closely correlated with income and urbanization but seems to be decoupled from the level of education. Our findings highlight something that still needs to be well highlighted in the literature: local conditions are an essential factor in purchasing decisions. This finding can represent a starting point for policy makers in formulating specific measures to stimulate the adoption of BEV + PHEV adapted to local conditions. In our study, the local conditions for adopting electric or hybrid vehicles are represented by the combination of purchasing power and prices for cars and fuel – included in AIC, the specific infrastructure – included in Pb_Ch_Points, the system of support measures – included in Incent_Leg_PEV. These elements significantly impacted the percentage variation of BEV + PHEV for passengers in the total fleet. At the same time, the variable related to the digital transformation of society had the most significant importance. This finding is in line with the results of the fourth edition of the European Investment Bank (EIB) Climate Survey (European Investment Bank, 2022) that shows that young people are the first adopters of new technology, representing the age category with the highest degree of digitization. Also, our results confirm studies (Christidis & Focas, 2019) showing that the urban population has a higher inclination to purchase such vehicles – in the urban environment, the infrastructure is better, and the level of digitization is higher; this trend also supports the finding regarding the differences between countries. Thus, on the one hand, in more developed countries, the differences between urban and rural environments are more attenuated. On the other hand, energy dependence is much higher in more developed economies, with a higher degree of industrialization. Thus, the role of conventional energy is more important in the industry.

The intention to purchase an electric or hybrid vehicle is determined, on the one hand, by consumers' control over the resources needed for the purchase. On the other hand, the purchase intention is strongly influenced by opinion leaders. They manifest themselves more firmly in highly digitalized economies and societies where the community plays a significant role. The idea of taking into account the level of education started from the results of previous studies that claim that a high level of consumers' awareness of the environment will also influence their behavioural intention to increase the propensity to buy more environmentally friendly vehicles (Di Felice et al., 2021; Sheth et al., 1991; Liao et al., 2017; Mandys, 2021; Buhmann & Criado, 2023). Our study did not confirm these considerations. On the other hand, however, our results agree with the results of the EIB survey (European Investment Bank, 2022), which shows that most young people in Europe, although they state their concern for the environment, say that they will fly to their next vacation destination. From a regulatory point of view, governments and manufacturers must consider the importance of promoting the sustainable development of the automotive industry. Moreover, the increasingly acute climate problems and the turbulence in the oil market make customers accept and gradually embrace the latest trend. However, consumers often show reluctant attitudes towards BEVs and PHEVs. Our analysis points out that the relatively high price combined with the reduced purchasing power is an important cause of this attitude, confirming the statements of (Tu & Yang, 2019).

According to Anthony Jnr (2021), digitalizing the electricity grid can improve existing electricity services in smart cities. Ekman et al. (2019) show that digitalization, along with technological innovation, can contribute to the development of smart cities, bringing environmental, social and financial benefits. These results are in line with our results which confirm our fifth hypothesis (H5).

## 6. Conclusions

The introduction of the hybrid electric vehicle has had significant benefits for the automotive industry and the environment. These benefits can be quantified in terms of reduced fuel consumption, lower greenhouse gas emissions, improved air quality, and economic benefits. HEVs have the potential to play a significant role in promoting a more sustainable transportation system and reducing the negative impacts of the transportation sector on the environment and public health.

This study adds perspectives on the intention to purchase electric or hybrid vehicles in EU countries and, at the same time, confirms certain previous findings. Thus, the obtained regression model shows that the willingness of the EU population to buy electric or hybrid cars is most strongly influenced in a positive sense by the support measures offered by governments. Thus, at a 0.13 increase in incentives for PEV, the percentage of BEV+PHEV for passengers in the total fleet rises by one unit. This result shows that the support of government policies has the most significant influence on customers purchasing electric or hybrid vehicles.

Our results also show that increasing the level of actual individual consumption by 0.014 leads to an increase of one unit in the percentage of BEV+PHEV in the total car fleet. Another result refers to the direct relationship between the inclination of citizens of EU countries to purchase an electric or hybrid vehicle and the level of digitalization of the economy. Thus, an increase of 0.04 in the digitalization level of the economy would lead to an increase of one unit in the percentage of BEV+PHEV in the total car fleet. Paradoxically, the charging infrastructure influences very little the willingness of the EU population to buy electric or hybrid cars. Thus, an increase of 0.00001 in the total number of regular and fast public charging points would cause the percentage of BEV+PHEV for passengers in the total fleet to increase by one unit.

The results of this study also highlight an aspect less evident in the literature, namely, local conditions. These conditions could include, in addition to the level of economic development, the level of education, the demographic situation, the local situation regarding mobility, and the cultural model. Also, the results suggest the need to increase the degree of involvement of political decision-makers to stimulate the population to purchase electric or hybrid vehicles. The fact that there are still differences between EU countries regarding the adoption of BEV and PHEV supports the idea that the development of electric vehicles still needs solid political support. Thus, to increase the adoption of environmentally friendly cars, governments should act to remove barriers and limitations and, last but not least, to promote the installation of charging stations.

Changing consumer attitudes is becoming a key factor in stimulating the growth of demand for electric cars in the next ten years while removing barriers to access. Thus, prices are becoming more affordable. The autonomy of such a car and the supply infrastructure, still deficient, are the factors that slow down the momentum of buyers.

With all these encouraging results, in 2024, the electric and hybrid car market was in free fall. Sales have dropped dramatically worldwide. To reverse these buying trends, policy makers could play an important role by initiating social marketing campaigns. They could use the effects of the innovation diffusion theory on the buying behaviour of electric and hybrid vehicles, as they are innovative products. Social media technologies could be an effective tool to foster interpersonal influence. On the other hand, governments should focus their educational efforts on people less inclined to innovation and risk in purchasing innovative goods, such as electric and hybrid vehicles, to expand the base of potential buyers.

## 7. Limitations and further research directions

Investigating the factors influencing purchasing cars in European Union form the perspective of buying electric and hybrid cars on change the contemporary business approach is a complex research topic and needs a further address due the massive transformations of the automotive and transportation paradigm change. The main limitations of the study are originated and include three main aspects: the datasets availability, the time span considered and the methodology employed. First, we acknowledge that variables datasets could be influenced by extract source availability differences, second our investigation is a one yearly based (2020) among the European Union (EU) countries and not considering a long data frame and third we have considered for the cross-sectional analysis and methodology associated. An important limitation of this study is that it did not consider emotional or cultural aspects. To better understand the causes of the differences between EU countries regarding the adoption of Battery Electric Vehicles and Hybrid Electric Vehicles, the research should consider the aspects related to emotions, psychology, and ethics in customers' behaviour.

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## Data availability

The data used in the research to support the findings of this study are included in the article.

## Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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# APPENDIX

## List of abreviations

BEV – Battery Electric Vehicles
PHEV – Plug-in Hybrid Electric Vehicls
EHV – Electric and Hybrid Vehicles
EVs – Electric Vehicles
ICEs – Internal Combustion Engines
GHG – Greenhouse Gas
AIC – Actual Individual Consumption
DESI – Digital Economy and Society Index
EAFO – The European Alternative Fuels Observatory
EU – European Union
EC – European Commision
ESA – The European Space Agency
VIF – Variance Inflation Factor
EIB – European Investment Bank
STRIA – Strategic Agenda for Research and Innovation in Transport

**Table A1.** Multicollinearity test

Variance Inflation Factors Date: 11/22/21 Time: 23:25 Sample: 1 27 Included observations: 27

| Variable | Coefficient Variance | Uncentered VIF | Centered VIF |
|---|---|---|---|
| C | 0.234293 | 39.59584 | NA |
| AIC | 3.45E-05 | 53.01085 | 2.129672 |
| PB CH | 3.52E-11 | 1.730512 | 1.371043 |
| INCENT LEG PEV | 0.003259 | 4.834424 | 1.237504 |
| DESI | 0.000107 | 53.58971 | 1.693640 |

**Table A2.** Serrial Correlation test

| Breusch-Godfrey Serial Correlation LM Test:<br>Null hypothesis: No serial correlation at up to 2 lags | | | |
|---|---|---|---|
| F-statistic<br>Obs*R-squared) | 1.003350<br>2.462017 | Prob. F(2,20)<br>Prob. Chi-Square(2 | 0.3844<br>0.2920 |
| Test Equation:<br>Dependent Variable: RESID<br>Method: Least Squares<br>Date: 11/22/21 Time: 19:59<br>Sample: 1 27<br>Included observations: 27<br>Presample missing value lagged residuals set to zero. | | | |

*End of Table A2*

| Variable | Coefficient | Std. Error | t–Statistic | Prob. |
|---|---|---|---|---|
| C | 0.344262 | 0.541858 | 0.635337 | 0.5324 |
| AIC | –0.003836 | 0.006476 | –0.592324 | 0.5603 |
| PB_CH | –2.27E–07 | 5.94E–06 | –0.038239 | 0.9699 |
| INCENT_LEG_PEV | –0.019530 | 0.059157 | –0.330130 | 0.7447 |
| DESI | 0.001039 | 0.010396 | 0.099961 | 0.9214 |
| RFSID(–l) | –0.394719 | 0.284625 | –1.386803 | 0.1808 |
| RESI D(–2) | 0.090892 | 0.260902 | 0.348377 | 0.7312 |
| R–squared | 0.091186 | Mean dependent var | | 4.24E–16 |
| Adjusted R–squared | –0.181458 | S.D. dependent var | | 0.367673 |
| S.E. of regression | 0.399642 | Akaike info criterion | | 1.221918 |
| Sum squared resid | 3.194273 | Schwarz criterion | | 1.557876 |
| Log likelihood | –9.495898 | Hannan–Quinn criter. | | 1.321816 |
| F–statistic | 0.334450 | Durbin–Watson stat | | 1.880187 |
| Prob(F–statistic) | 0.910643 | | | |

**Table A3.** Heteroskedasticity test

| Heteroskedasticity Test: Breusch–Pagan–Godfrey Null hypothesis: Homoskedasticity | | | |
|---|---|---|---|
| F–statistic | 1.589798 | Prob. F(4,22) | 0.2123 |
| Obs*R–squared | 6.054409 | Prob. Chi–Square(4) | 0.1951 |
| Scaled explained SS | 2.836517 | Prob. Chi–Square(4) | 0.5855 |
| Test Equation:<br>Dependent Variable: RESID^2<br>Method: Least Squares<br>Date: 11/22/21 Time: 19:57<br>Sample: 1 27<br>Included observations: 27 | | | |
| Variable | Coefficient | Std. Error t–Statistic | Prob. |
| C | –0.049548 | 0.182736 –0.271147 | 0.7888 |
| AIC | –0.000465 | 0.002219 –0.209679 | 0.8358 |
| PB CH | 2.95E–06 | 2.24E–06 1.314460 | 0.2022 |
| INCENT LEG PEV | 0.024006 | 0.021552 1.113907 | 0.2773 |
| DESI | 0.002598 | 0.003912 0.664061 | 0.5136 |
| R–squared | 0.224237 | Mean dependent var | 0.130177 |
| Adjusted R–squared | 0.083190 | S.D. dependent var | 0.157595 |
| S.E. of regression | 0.150897 | Akaike info criterion | –0.778860 |
| Sum squared resid | 0.500939 | Schwarz criterion | –0.538890 |
| Log likelihood | 15.51461 | Hannan–Quinn criter. | –0.707505 |
| F–statistic | 1.589798 | Durbin–Watson stat | 1.705957 |
| Prob(F–statistic) | 0.212287 | | |

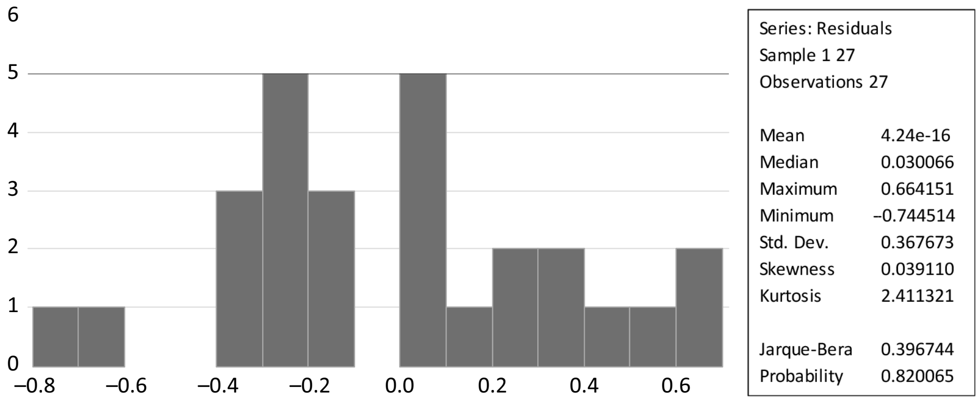


**Figure A1.** Residuals normality test