THE SPREAD OF ELECTRIC VEHICLES AND THE EXAMINATION OF THE FACTORS BEHIND IT ON A GLOBAL LEVEL

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Abstract: *Sustainable economic development, the sustainable competitiveness of countries, is one of the most researched economic issues of our time. This is not surprising, given the years of successive crises. Countries must continue to emerge from these crises without continuing to put pressure on the natural environment that underpins our existence. The spread of consumerism brings with it many environmental problems. The latter is borne out by the emissions of petrol and diesel vehicles. In order to reduce air pollution, the marketing and use of electric vehicles has become increasingly popular worldwide, including in Europe. But what about developing countries or countries with economies in transition? The present work is the introductory part of a larger research project, in which a document analysis based on secondary research was carried out by studying documents, laws and regulations. We sought to find out what factors, including governmental factors, have led to an increase in the number of electric vehicles placed on the market. Several countries were examined, grouped by economic development. We found that the level of economic development of countries influences the amount and extent of incentives introduced. To confirm this, a correlation calculation was carried out, which was not confirmed. However, it can be seen that the myriad of infrastructure, food, epidemiological and overpopulation problems that plague the economies of developing countries mean that local governments have less attention and financial resources to devote to pollution problems. We believe that our study and its continuation can be useful for all those who are interested in electric cars in any form.*

Keywords*: electric cars, plug-in hybrid, advantage, incentives, developed and developing countries*

JEL Classification: *O11*

1. Introduction

Currently, purchasing electric cars is becoming increasingly popular, partly due to the environmental and social benefits they provide during their operation. In the scope of the present study, the global and European spread of electric vehicles, the incentives that influence the purchasing behaviour of consumers and, in particular, the government policies that promote the increasing proportion of electric vehicles in circulation are discussed. Since the selling price of an electric vehicle is much higher than its combustion engine counterpart, and as the level of economic development and environmental awareness of countries differ, the comparison has been classified into development categories. It is assumed that the number of electric cars and the number of government incentives introduced in more economically developed countries is also higher than in less developed or developing countries. We also assume that there is a correlation between the evolution of the uptake of electric cars, the measures taken by governments to promote the market uptake of green plate vehicles and the level of economic development of the country.

2. The rise of electric vehicles in the world, Europe and Hungary

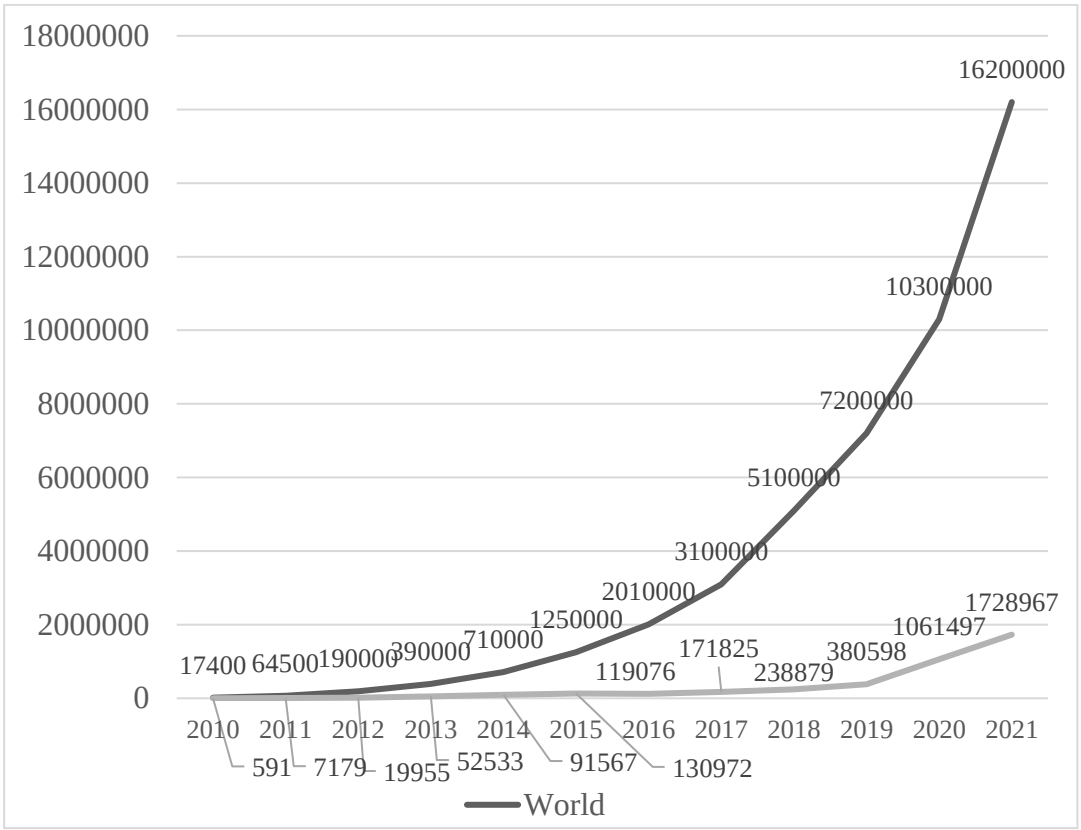
Surprisingly, the appearance of electric vehicles occurred before the invention of gasoline-powered cars. In the second half of the 20th century, with the emergence of consumer society, the number of goods produced and put on the market increased significantly, as did the amount of waste generated. As a result, the problems caused by increasing environmental pollution came to the fore (*Paulovics-Jámbor*, 2022).
The main environmental problem, apart from global warming, disproportionate recycling, ocean acidification and overpopulation is environmental pollution. Air pollution accounts for a huge proportion of this (*Salamon*, 2022). According to a WHO report, approximately 7 million people die each year worldwide from health problems caused by air pollution. In 2010, 223,000 people died of lung cancer (*Antal-Péter*, 2007). These two figures highlight why EU policymakers have devoted so much attention to environmental measures over the last two decades and why steps towards sustainability are becoming increasingly important for society. One of the fundamental positive aspects of electric vehicles is their ability to operate without emitting pollutants, and therefore contribute significantly to reducing global CO_2 emissions.

The first electric bicycle was created by Gustave Trouvé at the end of the 19th century, followed by the first electrically powered car in England in 1884 by Thomas Parker (*Egyperces*, 2021; *Ferencz*, 2021). In the USA, electrically powered vehicles were popular in the first half of the 1900s, however, with the spread of internal

combustion engines, they became less in demand. (*Adam*, 2018). The first mass-produced car was the Toyota Prius, which was launched in 1998 (*Szabó*, 2010). The Tesla, which was launched in the early 2000s, contributed greatly to the spread of electric vehicles (*Ádám*, 2018).

Due to the environmental and social benefits mentioned in the introduction, the number of electric cars is showing a continuously increasing trend worldwide. According to calculations by the International Energy Agency (IEA), at the beginning of the 2020s, five times as many electric cars were put on the market worldwide as in 2015 (*Nagy, 2022*). The following diagram (*Figure 1*) shows the number of electric cars in stock globally and in the European Union between 2010 and 2021. The automotive sector, like most industries, is significantly dependent on the current economic situation. The 2008 global crisis also brought enormous changes to the life of the industry. Likewise, the impact of the coronavirus pandemic has contributed to changes in the electric car market in 2021, both at national and company level (*Kiss*, 2015; *Kiss*, 2017; *Kiss*, 2019).

Figure 1: Number of electric cars in stock in the world and in the European Union from 2010 to 2021



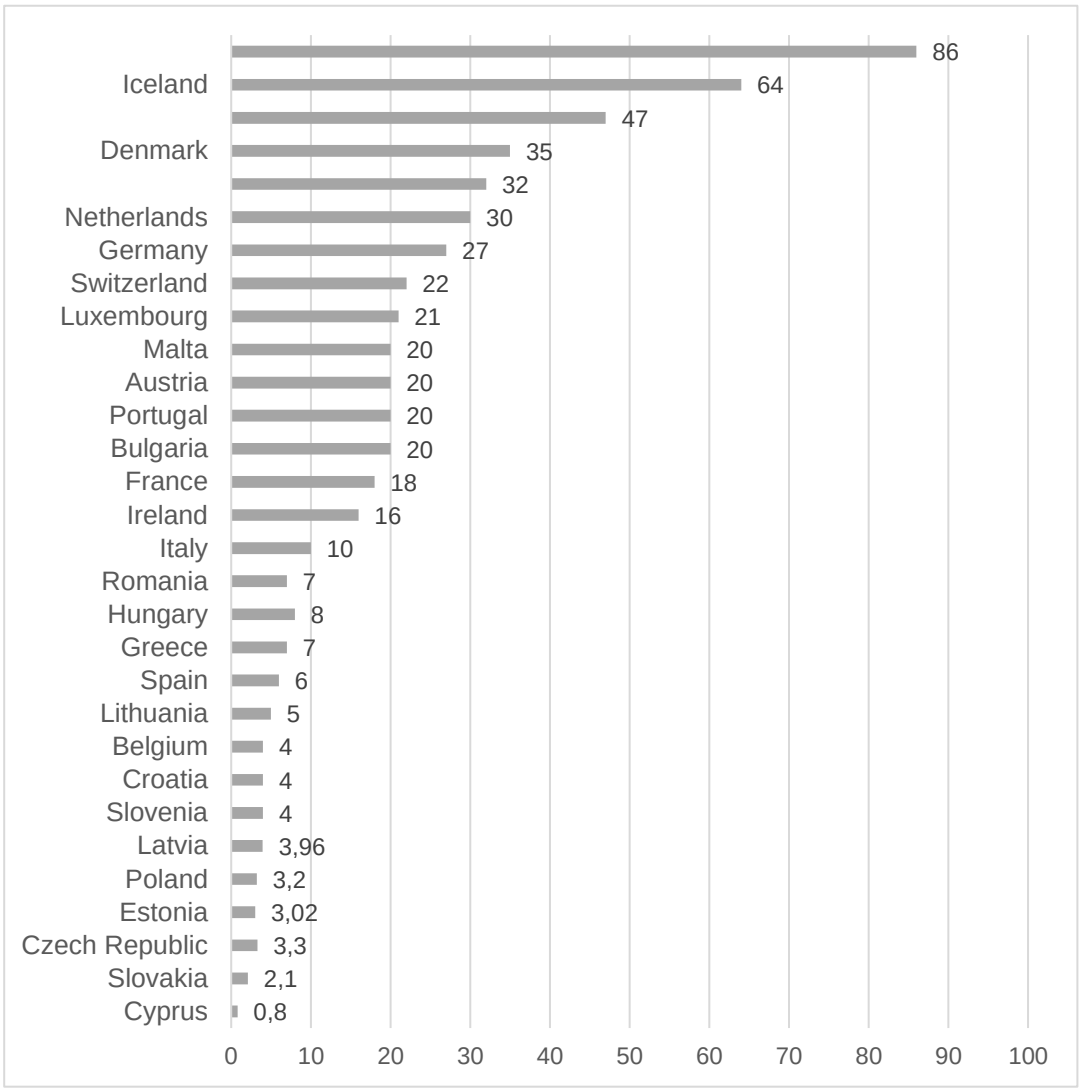
Source: own editing based on the data of (Camille, 2023) and (IEA, 2022)

It can be seen *(Figure 1)* that the number of cars with green licence plates registered in the world and in the EU is steadily increasing. At global level, the increase has been more pronounced since 2012, while in the EU it has been recorded since 2019. By 2021, the share of electric cars was 10.67% of the global total. In Europe, 10 times more electric vehicles have been registered in 2021 (1.7 million units) than in 2017. Since then, this share has shown a steadily rising tendency in a single year, with 22.9% more electrically powered cars on the market in January 2023 compared to the same period the previous year (*Camille*, 2023; IEA, 2022; E-cars, 2023). This shows that the spread of electric vehicles in Europe has increased significantly over the last 5 years, but despite the EU's commitment to sustainable environmental management over several decades, this growth is not considered sufficient.

China is the world's largest car market, ahead of the US. It's becoming a cliché, but China is slowly selling twice as many electric cars as Europe and the US combined. Since 2017, sales of conventional internal combustion vehicles have been steadily declining (23.562 million units), with roughly 9 million less sold in 2022 than five years ago (a 37% drop). In contrast, the number of new partially or fully electric vehicles sold (648 million units) has increased by more than ten times (6.887 million units) during the same period. Compared to the year 2021, in 2022 the sales of battery electric vehicles (BEVs) reached 5.365 million (an 81.6% increase), the number of plug-in hybrid and range-extended electric cars reached 1.518 million (a 151.6% increase), while 3,000 fuel cell cars were sold (an increase of 112.8%). Taking this trend into account, it seems realistic that China's projected total domestic vehicle sales in 2023 will reach 27.7 million units, of which 25% will be partly or fully electric vehicles (*Nauner*, 2023).

Figure 2 shows the ratio of newly registered electric cars to total passenger cars in Europe in 2021.

Figure 2: Share of newly registered electric cars in the total new passenger car fleet in Europe in 2021



Source: own editing based on the data of (Camille, 2023)

It can be observed that most of the electric cars were launched in Norway, where 86% of newly registered cars were electric. Iceland (64%) and Sweden (47%) also have a high proportion of cars with green licence plates (*Camille*, 2023). It is noticeable that the demand for electric cars is higher in Scandinavia and wealthier European countries, while in central, eastern, and southern parts of Europe, it is significantly lower. In 2021, less than 5,000 vehicles with green licence plates were registered in Hungary, while in 2022 this number rose to over 13,000 (*Növekedés.hu*, 2023). Subsequently, in the scope of the study, it was aimed to examine how the economic development level of a country and factors that can be influenced at the

national level to encourage purchasing behaviour can affect the spread of electric cars, and whether there are any best practices that can be highlighted to increase consumer purchasing intentions.

3. Factors that motivate consumers to purchase vehicles operating with an electric drive

The factors that motivate consumers to purchase vehicles with green license plates have been classified into three groups (*Table 1*): benefits arising from their operation, direct financial benefits, and incentives provided by governments. We believe that all three factors play a significant role in encouraging purchases. In the scope of the present study, the focus was on providing a detailed description of the latter group, taking into account the developmental groups of countries.

Table 1: Benefits of using electric vehicles

Benefits from operation	*Direct financial benefits*	*Incentives provided by governments*
operation without local emissions	lower maintenance charges for spare parts	provision of tax reductions
less noise pollution	one-third of fuel costs	parking discounts
less chance of damage to components		access to restricted areas with reduced traffic
reduced number of road accidents		the possibility of using bus lanes
lower risk of component failure		

Source: own editing based on the data of Felsmann, 2014; Ferencz, 2020; Firstrow, 2019; Horváth, 2018; Mester, 2019; Nagyváradi, 2015; Németh-Kőmíves, 2021; Németh-Kovács, 2022;

One of the advantages of the construction and operation of electric vehicles is that the vehicles belonging in this group are able to operate without the emission of pollutants, while their gasoline and diesel counterparts significantly pollute our environment *(Németh-Kovács*, 2022). One of the most important positive aspects of these cars is that they have a minimal noise impact. According to a report published by the WHO, the number of people affected by noise pollution worldwide is over 100 million, 20% of which are European Union citizens (*Németh-Kőmíves*, 2021). Flesmann also found that consumers are motivated to purchase electric cars mainly by the lack of local emissions, lower noise pollution and transportation discounts provided by governments (*Felsmann*, 2014). This can be explained by the fact that electric vehicles emit less pollutants due to energy-efficient braking and easier starting due to the high torque, and the simpler internal design means that there is

less chance of damage to components. In addition, according to a large number of scientific literature, the use of electric cars can reduce the number of road accidents. This is because automation avoids accidents caused by human error (*Mester*, 2019). In the scope of the publication of András Ferencz on electric cars, it is argued that they have a simpler structure than their gasoline or diesel counterparts and therefore have a lower chance of component failure (*Ferencz*, 2020). The use of electric cars is also more convenient, as drivers owning electric vehicles do not need to spend time and energy refuelling their vehicles, they are even able to do so at home and set off with a 'full tank'. In addition, in urban driving, drivers can use the accelerator pedal to increase the driving range, because in the minutes when the driver's foot is not on the accelerator pedal, the battery of the car starts to charge (*Horváth*, 2018).
The direct financial benefits arising from the use of electric vehicles include lower maintenance and servicing costs (*Mester*, 2019). This is due to the fact that the structure of the vehicles in this category is much simpler than that of their traditional counterparts, with much less "moving" parts, resulting in lower costs for spare parts (*Nagyváradi,* 2015). In addition, owners of electrically powered cars face fuel costs that are one third lower than those of conventionally powered cars. For those who have the possibility to charge their vehicle at home with a 30-40 kWh battery, the cost of a 150-250 km trip is only 1200-1600 HUF (*Firstrow*, 2019).
Incentives provided by governments are an indirect way to promote the growing popularity of electric vehicles. These incentives include the provision of tax reductions, discounted parking, access to traffic-reduced areas and the use of bus lanes. However, are there similarities or differences among these incentives, taking into account the development level of the countries?
The World Economic Situation and Prospects (WESP) publication classifies all countries in the world into three main categories. A distinction is made between developed countries, countries with economies in transition and developing countries. According to the United Nations (UN) 2020, developed countries include the European Union Member States, the United States, Canada, Norway, Switzerland, Australia, Japan, New Zealand and the United States of America. The rest of the world is listed as transition economies and developing countries. The transition economies of South-Eastern Europe are Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia. In addition, Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, the Republic of Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan and Uzbekistan are also transition economies. The rest of the world is classified as developing countries (*Statistical Annex*, 2020). Due to income differences, there are huge dissimilarities between developed and developing countries in terms of infrastructure, industrial

competitiveness and consumer awareness. The market of developing countries accounts for only 20% of global car sales. In the third quarter of 2022, battery electric vehicles accounted for more than 10% of the total vehicle fleet in Europe, China and Korea, while in Russia and Latin America the share was less than 1% (*Hold*, 2023). In our view, it is particularly important that local governments in the latter countries introduce more measures to support the purchase of electrically powered vehicles.

Table 2 summarises government measures to encourage the purchase of electric passenger cars in the countries involved in the present research, classified by level of economic development. *In Brazil*, which is one of the developing countries, individuals and companies importing electric vehicles and their components into the country are exempted from paying 35% import duty. According to literature, the government measure would result in a total loss of customs revenue of USD 3.6 billion, or HUF 13.3 billion, for the Brazilian government over the period from 2015 to 2022. However, the measure seems to have delivered the expected results, as the number of electric and hybrid vehicles on the market increased from 846 to approximately 126.5 thousand during the analysed period (*Totalcar*, 2023; *Statista*, 2023). *In Mexico*, the state does not provide incentives for the purchase of electric cars, resulting in a very low number of electric cars on the market. In 2022, only 0.5% (almost 50,000) of all vehicles sold in the country were electrically powered (*Autropro.hu*, 2023). Among the transition economies, the use of electric vehicles in Albania, Kosovo, Macedonia, Bosnia and Herzegovina and Montenegro is not yet supported by government incentives (*National Electromobility Strategy (Hazai Elektromobilitási Stratégia)*, 2023). *In Russia*, the concept of electric vehicles for 2030 is that one in 10 cars will be electric. The goal set by the Russian government in 2020 was to establish a minimum of 72,000 electric charging stations and 1,000 hydrogen fuel stations, as well as manufacture 217,000 electric vehicles. To achieve this goal, the government planned to allocate 10.5 billion dollars. Their objective is to put 1.5 million electric cars on the market (18,700 in July 2022) and to equip the country with 20,000 more electric charging stations (*Pankova*, 2021; *E-cars*, 2021a; *E-cars*, 2021b). However, the ongoing war in Russia makes it unlikely that these goals will be achieved. *In Serbia*, the government subsidises the purchase of passenger transport vehicles with a maximum of nine seats and electric trucks of less than 3.7 tonnes with dinars equivalent to 5,000 EUR, except for taxi drivers receiving vehicle purchase subsidies (*Vajma*, 2022). *Belarus* aims to have at least 100,000 electric vehicles on its roads by 2025. To achieve this, the government has already introduced welfare subsidies in 2020 (*Manly*, 2021).

Table 2: Incentives introduced by governments

Economic development level Name of country	**Government measures introduced**
Developing countries	
Brazil	exemption from import duties
Mexico	no incentive factor
Countries with economies in transition	
Russia	provision of financial support for the installation of public charging stations and the development and production of electric cars
Serbia	financial support for electric vehicle consumers
Belarus	introduction of welfare subsidies
Developed countries	
Hungary	free parking
Netherlands	exemption from the obligation to pay vehicle tax
Sweden	granting of tax relief
Denmark	determining the level of vehicle tax to be paid on the basis of CO_2 emissions
Norway	VAT-free purchase
France	provision of social leasing for lower-income families

Source: own editing based on the data of Totalcar, 2023; Autropro.hu, 2023; Autropro.hu, 2023; National Electromobility Strategy, 2023; E-cars, 2021b; E-cars, 2021a; Vajma, 2022; Manly, 2021; Electric Car Drivers (Villanyautósok), 2023; Honda, 2022; Lovasi, 2022; Greendex, 2020; Autopro, 2023; E-cars, 2022; ABN, 2023; based on data from Autropro.hu, 2023;

Among the *economically developed countries***,** in Hungary local governments regulate local parking through ordinances. Many city authorities allow owners of vehicles with green licence plates to park for free in their municipalities. In Budapest, drivers of electric cars can park free of charge in all districts of the capital, except for the municipal pay car parks in Alíz Street and Normafa in the 11th district. The Municipality of Debrecen currently offers free parking to private residents of Debrecen who are pre-registered and have a purely electric car. In Miskolc, pre-registration and having a clean electric vehicle are also a condition for free parking. In addition, in Balassagyarmat, Cegléd, Eger, Gödöllő, Gyöngyös, Hajdúnánás, Hajdúszoboszló, Harkány, Hatvan, Hévíz, Kisvárda, Monor, Orosháza, Salgótarján, Siklós, Sopron, Székesfehérvár, Szilvásvárad, Tamás, Tapolca, Tatabánya, Vác, all drivers with green licence plates can park for free without any further conditions (*Villanyautósok,* 2023). In *the Netherlands,* ¼ of all new cars on the market in 2020 were electric vehicles or hybrid transport vehicles. This is largely due to the fact that the Dutch government is trying to increase the number of electric vehicles registered

in the country by offering tax incentives and various subsidies. The Member State will exempt car owners with green licence plates from vehicle tax until 2024. As of 2025, a 75% discount will be granted to car owners in this category. In addition, the increase in the number of electric vehicles is also attributed to the fact that the Netherlands has the largest number of charging stations in Europe, which makes the electric vehicles ready for transportation. (*Honda*, 2022). *In Sweden*, from 2018, owners of cars with green licence plates will benefit from a tax reduction and the government will also provide a total of 60,000 Swedish kronor, or around 2.2 million HUF, to encourage the purchase of electric cars. As of 1st January 2023, the condition for receiving the financial contribution is the purchase of a new car with CO_2 emissions below 60g/km or a natural gas/biogas engine. From 2018 until December 2022, new car owners with CO_2 emissions below 60g/km were also eligible for the subsidy (*Lovasi*, 2022). *In Denmark*, the local government aims to reduce greenhouse gas emissions by 70% by 2030. To achieve this, the plan is to increase the number of electric cars in the country's fleet to 775,000. In order to encourage the public to purchase cars with green licence plates, the vehicle tax rate of the country will be based on carbon dioxide emissions (*Greendex*, 2020). *In Norway*, electric cars can be purchased VAT-free and the local government also offers free parking, ferry use and toll-free parking in many cities for drivers with green licence plates. The measures introduced by the Norwegian government to promote the use of electric vehicles are proving to be successful, as Norway had the highest share of newly registered electric cars in the European Union as a percentage of total passenger cars (*Honda*, 2022). As the regulations introduced by the government have achieved the desired results, starting from January 1st, 2023, in order to ensure budget revenue, only purchases worth up to 500,000 Norwegian kroner, which is approximately 19 million Hungarian forint, will be eligible for tax exemptions. For vehicles with a purchase price exceeding this amount, the taxpayer will not be exempt from paying VAT on the portion above 500,000 Norwegian kroner (*Autopro*, 2023). *In France*, a programme is planned to elaborate a strong incentive for the use of electric cars. Under an initiative called 'social leasing', the government will allow lower-income families to lease a purely electric car for 100 EUR per month. This will allow families to use a vehicle with a green licence plate at a lower cost than the maintenance of an internal combustion engine car (*E-cars*, 2022). *In Germany, as* of 1st January 2023, those purchasing an electric vehicle with a net purchase price of up to 40,000 EUR will receive a subsidy of 4.5 thousand EUR, while those purchasing a car with a net purchase price of between 40,000 EUR and 65,000 EUR will receive a financial contribution of 3,000 EUR. It can be seen that, as in Norway, policy-

makers in Germany have reduced the level of support, as the number of electric cars coming on the market has increased substantially (*ABN,* 2023).

4. Supporting the formulated hypothesis with statistical methods

The hypothesis formulated at the beginning of the research, which stated that there is a strong correlation between the spread of electric vehicles, the measures introduced by governments to promote the market entry of vehicles with green license plates, and the level of economic development of the country, has been proven to be true. However, this is contradicted by the results of the correlation analysis used.

In the scope of the literature review, it was found that countries classified as developed according to the UN have a higher stock of electric cars than developing and transition economies. In addition, in most developed countries, the adoption of measures by governments and local authorities to promote the market spread of electric cars is widespread, while in less developed and transition economies, the they are only implemented in a few exceptional cases.

The hypothesis was tested at the beginning of the research using Pearson correlation analysis. To measure the level of development of a country, the value of the human development index, or HDI, for the year 2021 was examined. Surprisingly, the analysis revealed a negative correlation between the HDI parameter of a country and the number of electric cars in the fleet in that country, with a Pearson correlation coefficient of -0.18. According to the literature, the value of the HDI index is calculated on the basis of life expectancy at birth, the expected number of years of education, the actual number of years of education and the Gross National Income (GNI). The calculations show that an increase in the gross national income (GNI) and the actual number of years of education has a negative effect on the number of vehicles with green licence plates, while an increase in the life expectancy at birth and the number of years expected to be in education has a positive effect.

5. Conclusions

Very few government incentives for developing countries have been identified in the literature. It can be concluded that, in general, these countries are characterised by a lack of attention and funding from local governments to address the problems of environmental pollution, due to the numerous problems related to infrastructure, feeding, epidemiology and overpopulation that challenge their economies. In general, the number of registered electric vehicles in these countries is extremely low as a consequence. According to a report by the International Energy Agency, sales

of green licence plate vehicles in developing economies are mainly low due to high acquisition costs and lack of infrastructure needed to support the use of these vehicles. Most of the factors that characterise developing countries can also be valid for of countries with transition economies. Although it is believed that these states are more developed both economically and in terms of infrastructure, the attitude of the local government is a major determinant of the lack of action to promote electro-mobility.

In recent years, the market for electric cars has expanded rapidly in developed countries. In these countries, it is particularly important that governments encourage local residents to use electric vehicles to an appropriate extent, as according to the regulation adopted at the plenary session of the European Parliament on February 14, 2023, from 2035 onwards, new passenger cars and light commercial vehicles sold in the European Union must be electrically powered (*HVG*, 2023). To achieve this, most EU Member States are encouraging individuals and companies to buy and sell electrically powered vehicles by offering tax incentives, subsidies for purchases, as well as reduced parking and road use fees. Of the Member States covered by the study, Norway has been the most successful, with green licence plates cars accounting for the largest share of new vehicles on the market. As explained in the previous chapter of our study, the Member State has already reduced the support measures introduced, as the number of electric cars entering the market is increasing rapidly, and the government could therefore take the measure to reduce the support in order to increase the budget revenue. A similar trend can be observed in Germany. The hypothesis formulated at the beginning of the research, namely that there is a strong correlation between the spreading of electric cars and the measures introduced by governments to promote the market penetration of vehicles with green licence plates and the level of economic development of the country, proved to be true. However, the statistical analysis refutes this claim. Given the discrepancy in the results, it is believed that further research is required on the topic.

It is not possible to highlight a governmental "best practice" to encourage electric car sales for all countries, but it is believed that countries with a typically lower share of electric cars on the road should study the electro-mobility strategy of those countries where the number of vehicles with green licence plates on the market has reached the target. Excellent examples are the "tactics" used by the Norwegian and German governments, or the French plan to develop "social leasing" in countries with high rates of low-income households. It is also suggested that, although this was not the focus of the study, the real role of electric cars in environmental protection and human health should be examined by research groups at multiple levels. In addition to the advantages of electric cars, their disadvantages must also be taken into account,

in addition to the current technical and technological conditions (e.g. battery production, Faraday cages). Car production does not start in the car factories, but with the extraction of raw materials, followed by the manufacture and transport of certain components to the country of manufacture. In order to preserve and sustain the population, our planet and the future of the automotive industry, it is necessary to put cars on the market with technology that will serve us all in the long term; the design of that is in the hands of national governments.

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