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Overview of European patents in Germany, France and Spain, with a potential application to the development of electric vehicles

Boglárka Konka – Anita Veres

Within the Green Deal's 'Accelerating the shift to sustainable and smart mobility', vehicles with alternative propulsion systems will play a significant role, as the transport sector is responsible for one-fifth of the European Union's CO_2 emissions. Therefore, more and more governments are supporting the purchase and production of electric vehicles, as it can be one of the main tools for locally reducing fossil fuel consumption as well as reducing CO_2 emissions. The analysis highlights that the three most important vehicle-producing countries (based on 2019 OICA data) from the European Union are Germany, France, and Spain. The development trajectory of these countries in the field of electromobility is presented using descriptive statistics. Sustainable development goals can be achieved by creating an innovative environment and overcoming barriers to innovation, which can be indicated, for example, by the number of patents in a given country. Therefore, a long-term time series based on patents related to electric vehicles will be explored using the database of the European Patent Office. The study describes the vehicle manufacturers with the most patents, and the main patent areas in the three countries analysed.

Keywords: electric vehicle, Germany, France, Spain, patent analysis.

1. Introduction

This study focuses on the European vehicle manufacturers with the most patents in select countries, and their main patents that have relevance in the development of electric vehicles. As part of this study, we analyse the electric car market in Germany, France and, Spain, as well as relevant information about these three countries and their automotive market. These countries were selected since they are the main car manufacturers in the European Union, based on the database of the International Organization of Motor Vehicle Manufacturers (OICA) in 2019 (OICA 2019). We also summarize the tendencies and the factors that influence the proliferation of electric cars. Finally, we analyse the patent applications of the given countries as an indicator of the progress and the commitment of car manufacturers towards electric vehicles.

2. Background information

This section introduces the main strategy of the European Union to address climate change. That action could influence the decision-makers all over the EU including Germany, France, and Spain. The second part of this section describes the main characteristics of the electric car market in the countries analysed.

2.1. European Green Deal

Climate change and environmental degradation are a real threat to Europe and the world. To meet these challenges, the European Union has developed a new growth strategy that will transform it into a modern, resource-efficient, environmentally friendly, and competitive economy. The goal is to have zero greenhouse gas emissions in the EU by all industrial production processes, as well as vehicles involved in all forms of transportation, by 2050.

The European Green Offer is a plan to make the European Union economy based on a sustainable business model with a focus on zero CO_2 emissions (see Figure 1). The way to bring about these changes is to solve climate and environmental challenges and to make the transition fair and economically accessible to consumers. The operational benefit of the European Green Deal is to promote resource efficiency through the transition to a clean, circular economy and the restoration of biodiversity, and the reduction of pollution and waste, throughout the entire life-cycle of products. The plan outlines the investments required to achieve a successful transition as well as the available funding instruments. It explains how to ensure realism and an all-encompassing transition phase. The European Union aims to be climate-neutral by 2050.

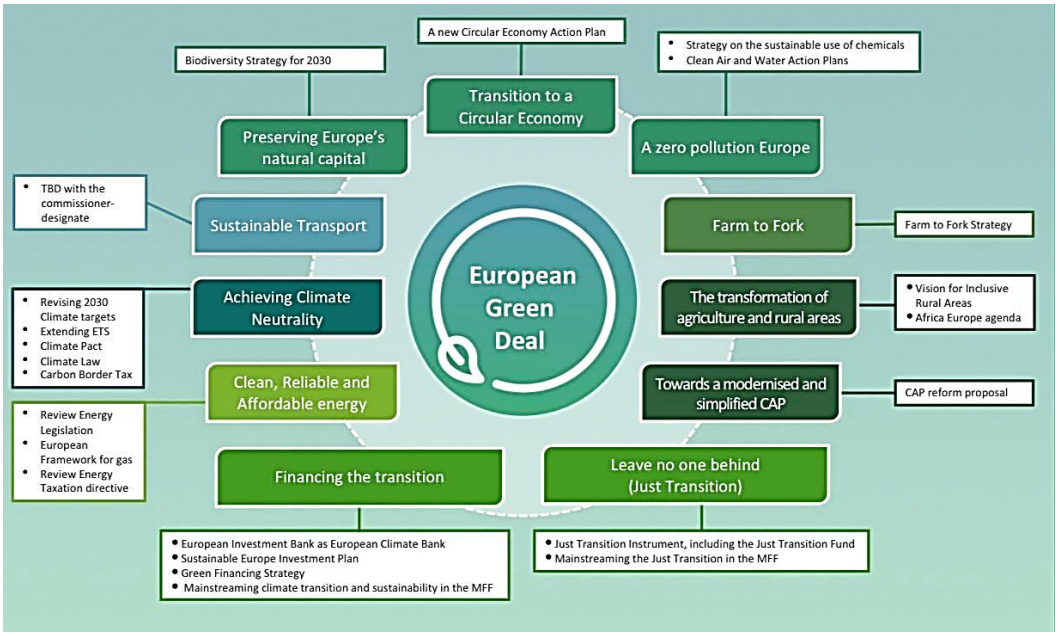
To achieve this goal, there is a need for all sectors of the European Union economy, including the development and introduction of environmentally friendly technologies, support for industrial innovation, and the introduction of private and public transport in cleaner, cheaper and healthier forms, to decarbonize the energy sector. The European Union provides financial support and technical assistance to help those affected by the transition to a green economy (European Commission 2021).

However, all electric vehicle patents may not be supportive of the sustainability portion of the EU Green New Deal, since the entire life-cycle of electric vehicles and their components must be taken into consideration. For example, advances in battery technology may not necessarily address the issue of how to recycle dead batteries with minimal impact on the environment.

The European Commission has 10 key areas for action and 82 start-up decisions to make the vision a reality. The sustainability of transport depends on increasing the number of zero-emission vehicles, ships and aircraft, renewable and low-carbon fuels, and related infrastructure. To this end, the goal is to install 3 million public electric charging stations by 2030 (European Commission 2020).

Electric vehicles are important to European industry for many reasons. They will bring new market opportunities and new jobs. At the same time, they would provide better energy efficiency and reduce greenhouse gas emissions. The development of an electric vehicle industry requires considerable investments in research, technology, and development support for the reaction of new markets and new business models but also changes in the mobility behaviour of both individual people and the society as a whole (European Parliament 2010).

Figure 1 European Green Deal Goals



Source: European Commission (2019)

In addition, the advancement of electric cars could have a major impact on the already transforming automotive industry. An example is Tesla, which uses non-traditional sales and marketing methods (see Thomas–Maine 2019, Falát–Holubcík 2017). At the same time, the automotive industry is a significant player in terms of economies, as it is a major exporter, contributor to GDP, and employer. Thus, the welfare of the analysed countries can be strongly influenced by the competitiveness of the automotive industry. An additional statistical argument also supports the analysis of the automotive industry, as there could be a correlation between living standards and the number of cars (Fleischer 2011, Szalavetz 2013). On the other hand, vehicles, like passenger cars, have increased individual mobility, thus giving people more freedom, and reshaping environmental and social attitudes.

2.1. The electric car market in Germany, France, and Spain

Our study summarizes the main information about the German, French and Spanish car markets. Based on the database of the International Organization of Motor Vehicle Manufacturers (OICA), passenger car production decreased in Germany, France, and Spain in 2020 compared to the previous year. One of the reasons was the spread of Covid-19, which caused a considerable challenge for the automotive manufacturers. The average pandemic-related shut down duration was 30 working days in Germany, and 34 working days in France and Spain during March, April, and May 2020 (ACEA 2020a).

The estimated loss in production was the highest in Germany within the European Union (616,591 vehicles). It affected 568,518 employees there (ACEA

2020a). Compared to the number of employees in the German automobile industry in 2020, the effects of the pandemic could influence about 70% of the employment (calculated based on the Statista.com database). It is possible that its total effects could be higher because the number of employees in the industry decreased by about 3% in Germany (Statista 2021).

It is an interesting fact that electric car manufacturing in Germany was able to continue its growth trajectory despite Covid-19. It achieved increasingly higher proportion rates within the German production between 2019 and 2020, based on the dataset of Verband der Automobilindustrie (VDA 2021).

The number of total car sales in 2020 also declined in each country that was analysed, as shown in Table 1. The most significant decline was in Spain in 2020. This is not surprising since the Spanish real GDP per capita value also decreased by the largest percent among the three countries. Car sales are sensitive to effects on the economy. If a recession or depression were to occur in the economy, the car sales could drop dramatically as they did during the 2008 financial crisis (for more information, see Grigolon et al. 2016, Sass and Szalavetz 2013, ACEA 2010, and Haugh 2010). Based on the research of the Deloitte Insights, a significant proportion of the Spanish (56%), French (51%) and the German (40%) consumers said that they intend to keep their current vehicle longer than they originally planned (Deloitte Insights 2020) because of the uncertainty caused by Covid-19. This could result in causing a similar drop in car sales as was experienced in 2008.

Table 1 Main indicators of the German, French and Spanish automotive industry

2020 (*change compared to the previous year*)	**GERMANY**	**FRANCE**	**SPAIN**
Passenger car production	3,515,372 cars *(–24.6%)*	927,718 cars *(–44.6%)*	1,800,664 cars *(–19.9%)*
Passenger car sales	2,917,678 cars *(–19.1%)*	1,650,126 cars *(–25.5%)*	851,213 cars *(–32.3%)*
Passenger cars in use (2019)	47,715,977 cars *(+1.3%)*	32,416,180 cars *(+1.2%)*	24,558,126 cars *(+2.0%)*
Passenger cars per 1,000 inhabitants (2019)	574 cars *(+1.2%)*	482 cars *(+0.8%)*	519 cars *(+1.2%)*
Real GDP per capita	34,110 euro (–4.9%)	30,480 euro (–8.4%)	22,350 euro *(–11.3%)*

Source: Self-created table based on Eurostat (2021a), (2021b), and (2021c); OICA (2021a) and (2021b) datasets.

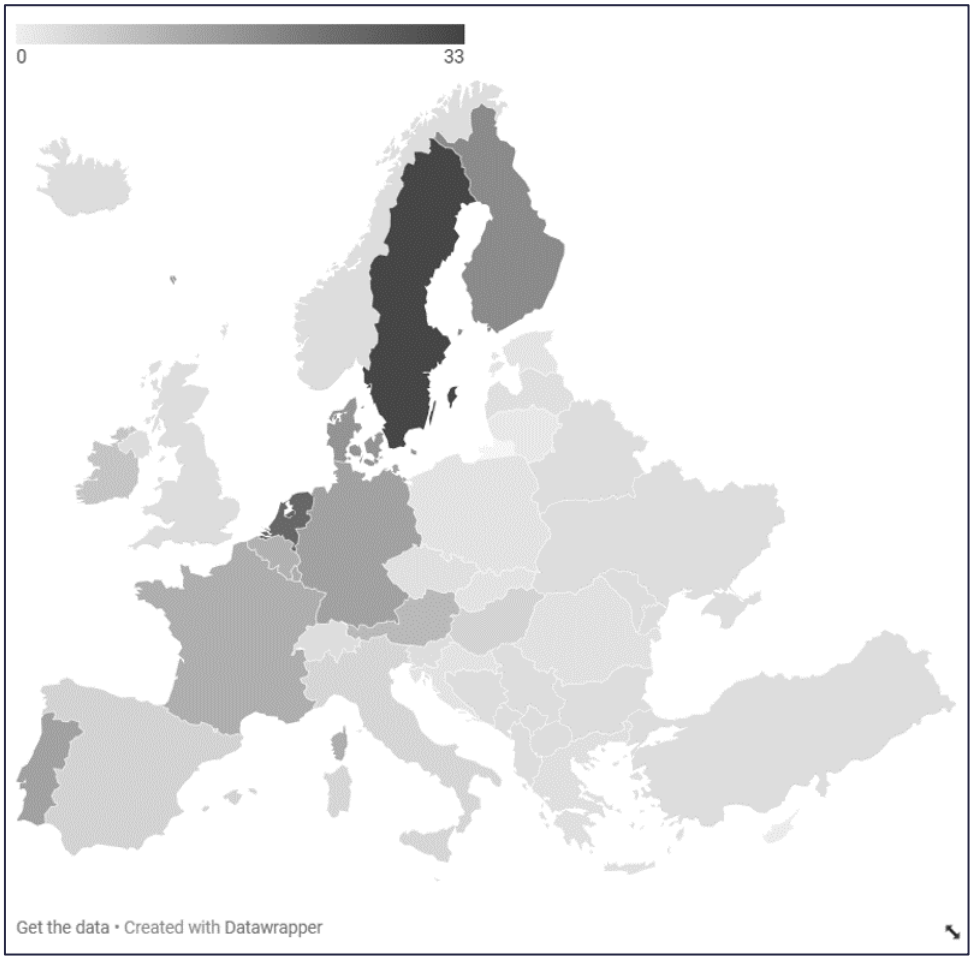
Table 1 also includes figures on the passenger cars in use and the passenger cars per 1,000 inhabitants, because the market size also could affect the proliferation of electric cars. Both data came from 2019, therefore, they were not influenced by the Covid-19 pandemic. The indicator relative to population may give a more reliable picture, as it also considers the population of the given country.

But both indicators showed small increases in the three countries. This could be a positive effect because it means a potentially significant market for electric cars, and it could benefit the well-being of the inhabitants. On the other hand, it was a negative consequence, because there are more cars on the road which produce more air and noise

pollution and emissions. From Table 1 it could be assumed that the proportion of electric cars of new car registrations is the highest in Germany.

After a general picture of the car industry in Germany, France, and Spain, the study visualises the main tendencies of the electric car market within the countries analysed. Figure 2 illustrates the proportion of electric cars within all new car registrations in the European Union in 2020. Based on the figure we could assume a strong connection between the GDP per capita and the penetration of electric cars. Among the three countries analysed, Germany (13.5%) had the highest proportion, France came next (11.3%), and finally Spain (4.84%) in 2020.

Figure 2 The proportion of electric cars within new car registrations in EU-27 (%), 2020



Source: Self-created figure with Datawrapper based on the ACEA (2021) dataset

The order shown in Figure 2 can also be observed in the growth rate compared to the previous year. The number of electric cars rose by nearly 263 percent in Germany, 202 percent in France, and 136 percent in Spain in 2020, as calculated based on the ACEA

dataset (ACEA 2021). That trend was mainly due to government subsidies (for example, tax benefits and purchase incentives of electric vehicles).

Despite the high growth rates, the numbers showed that the proportion of electric cars was quite low in 2020, especially since the figures include two categories: battery electric vehicles (BEV), and plug-in hybrid electric vehicles (PHEV). The operation of the BEV could be locally neutral to the environment (Milev et al. 2021, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2019, Gopal et al. 2018) because it does not contain an internal combustion engine, fuel tank, or exhaust pipe. Therefore, an ever-increasing number of governments support the purchase of these vehicles.

On the other hand, the production of electric cars, charging materials (if the electric car owners charge it with electricity generated by a thermal power plant) or the mining of its raw materials could also increase the emissions and environmental pollution. Consequently, the sector needs significant developments to become environmentally friendly in the future (Nanaki 2021, Hussain et al. 2020, Kasti 2017). Those innovations could cause some spill-over effects to other sectors, such as in the production of laptop computers or mobile phones (Mester 2019).

In the second type of electric vehicle (PHEV), there are internal combustion engines as well as electric motors. Hence, it could use only its battery power. However, the advantages of internal combustion (like the short charging time) also characterize it, so there is no need to change the daily routines of the owners. As Table 2 shows, most buyers preferred the cars from the PHEV category in 2020 in the countries analysed: their growth rates were higher in the three member countries, and its new car registration compared to the previous year was also greater than that of the battery-electric cars in Germany and Spain.

Table 2 Comparison of new Battery Electric Cars, Plug-in Hybrid Cars and Hybrid car sales in Germany, France, and Spain in 2020

2020 ***(change compared to 2019)***	**GERMANY**	**FRANCE**	**SPAIN**
Battery Electric Cars	194,474 cars *(206.3%)*	111,127 cars *(159.48%)*	17,927 cars *(78.52%)*
Plug-in Hybrid Cars	200,469 cars *(342.07%)*	74,592 cars *(301.20%)*	23,306 cars *(213.59%)*
Hybrid cars	327,395 cars *(68.85%)*	168,873 cars *(58.15%)*	137,425 cars *(26.45%)*

Source: Self-created table based on the (ACEA 2021) dataset

Table 2 also highlights the leading role of hybrid passenger cars (HEV), but these do not fall into the category of electric cars. The HEV category includes vehicles that are powered by internal combustion engines (ICE) but have one or more electric motors. The electric motor provides extra power, therefore the size of ICE could be smaller than the traditional versions (without an electric motor). The main difference between the HEV and the PHEV is that the HEV could not be charged by off-board sources. It uses regenerative braking and an internal combustion engine to capture energy. In contrast, a PHEV could be plugged into off-board sources of electricity to charge its battery.

Strong support by the government was an important factor in the demand for electric passenger cars in 2020. This connection is a rapidly expanding research topic in the literature (O'Neill et al. 2019, Liao et al. 2017). But its effects cannot be determined conclusively. For instance, some studies found that the tax reduction could be an effective action to influence the proliferation of electric cars (O'Neill et al. 2019, Glerum et al. 2014, Hess et al. 2012), however, there are some other factors as well (Endo et al. 2016, Hess et al. 2012, Zhang et al. 2011). Therefore, the financial incentives could be an essential component because of the inherently high price of electric cars, but its effectiveness may be significant only above a minimal cost threshold (Sierzchula et al. 2014, Jenn et al. 2013).

For example, in Norway, the owners of electric cars gained various benefits in 2020, such as tax exemption of green cars (for example no weight tax, CO_2 tax, or VAT), or lower parking fees (Norskelbilforening 2021). Because of the various state actions, 54 percent of new car sales were purely electric in Norway in contrast with 8 percent of petrol-only and 9 percent of diesel-only in 2020 (Klesty 2021). The Norwegian decision-makers have been motivated to encourage the purchase of electric cars since the 1990s. However, the data show that the penetration of electric cars was a slow process. Moreover, Norway has high GDP per capita based partly on its oil and gas exports, therefore they are better able to apply for such subsidies and investments than less wealthy countries (Heymann 2020). On the other hand, electric cars could be climate-friendly in Norway because their main source of electricity is hydropower (Heymann 2020). This fact also could increase the demand for those cars in Norway.

Similar motives are present in Germany, France, and Spain as well. Table 3 sums up the tax benefits and the purchase incentives of electric cars. In our study, we highlight the second option because the tax benefits are not the best alternative to motivate the demand for electric vehicles, as stated in the literature (for example Yan 2018).

Table 3 Tax benefits and purchase incentives for the electric vehicles in the countries analysed in 2020

2020	GERMANY	FRANCE	SPAIN
Tax benefits of electric vehicle (purchase, owners)	Temporary VAT reduction from 19% to 16% (between 1 July 2020 and 31 December 2020). 10-year exemption for BEVs and FCEVs registered until the end of 2020.	Regions provide an exemption for alternatively-powered vehicles. -	Exemption from 'special tax' for vehicles emitting up to 120g CO_2/km, and VAT exemption for alternative-powered vehicles in the Canary Islands. 75% reduction for BEVs in main cities.
Purchase incentives of electric vehicles	Environmental and innovation bonus	Bonus to purchase car or van with ≤20g CO_2/km. Scrappage scheme.	Incentive scheme

Source: Self-created table based on the (ACEA 2020b) dataset

In contrast to the Hungarian support system, the three countries analysed promote the buying of BEVs and PHEVs. Not surprisingly, Germany has the highest government assistance for the purchase of electric vehicles. There was no price limit, but two price categories existed in 2020. The customers who buy vehicles with an equal or lower net list price than €40,000 in Germany can gain a €9,000 bonus if they choose a BEV or FCEV[5], or a €6,750 bonus for a PHEV. If the car's net list price is more than €40,000, the state aid promised a €7,500 bonus for BEVs, FCEVs, and €5,625 for PHEVs in 2020 (ACEA 2020b).

For example, the price of the Volkswagen ID.3 reduced to €23,430 because of the bonus by the government. It means that its price became lower than the e-Golf (Mk7 Golf platform), or the new ICE-powered Mk8 Golf (Ramsey 2020, VolkswagenAG 2020). Finally, in 2020 the Volkswagen ID.3 was the 4th bestselling electric car in Germany, even though it was launched in the summer of 2020 (Best-selling-cars.com 2020a). That case showed how government policy can influence the demand for electric vehicles.

Financial support is high in Germany, and it is not random. The aim of the German Climate Action Programme 2030 is to reduce transport-related emissions by 40-42 percent by 2030. It means that more electric cars need to be out on the roads. The government planned that there will be 7-10 million electric vehicles registered in Germany by 2030. Therefore, the number of charging stations will be 1 million in 2030 (Bundesregierung 2019).

The French decision makers also determined the price limits. However, in the purchase incentives, they did not regulate the type of electric or alternatively-powered vehicles. The support was there for the purchase of cars or vans which have a lower emission than 20g CO_2/km. If the price of the car was lower than €45,000, then the households could get €7,000 and the legal persons gain €5,000 in 2020. If the vehicle price was between €45,000 and €60,000, the aid for the legal persons was €3,000 for the households. In the case of the FCEV, if the price of the car or van is higher than €60,000, then the household or the legal persons could receive also €3,000.

In France, there was a scrappage scheme for the purchase of second-hand or new vehicles with ≤50g CO2/km, if the price was lower than €60,000. The household's support was €5,000, and a legal person could get €2,500 in the case of the purchase of a car. The state aid was €5,000 for households or legal persons as well if they bought a van with the given details (ACEA 2020b).

To motivate the demand for electric vehicles more, the French policymakers signed the Objectif 100,000 Bornes Charter in 2020. The goal of that document is to build 100,000 public charging stations with a budget of €100 million much faster than previously scheduled, by the end of 2021 instead of 2022 (Union Francaise de l'Électricité 2021).

In Spain, there were no price limits in 2020. The incentive scheme supported the private purchases of BEVs with €4,000 – €5,000. It was almost half of German bonus. Purchase of PHEVs was rewarded with €1,900 – €2,600. In the case of the vans

[5] It is the acronym of fuel cell electric vehicles, which are powered by hydrogen. That type of vehicle also does not produce tailpipe emission.

and trucks, the aid is between €4,400 and €6,000 for private individuals, depending on scrapping (ACEA 2020b). The penetration of electric cars is lower in Spain compared to France or Germany, and the main fleet of that type of vehicle could be found in Madrid and Barcelona.

The financial incentives were not the only factors that could influence the demand for electric cars. The literature indicated other factors as well, such as the acceptance of that vehicle type by individuals and companies (Wallis–Lane 2013), the infrastructure investments (Sierzchula et al. 2014, Brand 2016), or social norms (Barth et al. 2016). The up-to-date information could also affect the decision of the consumers.

For example, an American study analysed the lack of knowledge with a questionnaire that was filled out by 502 people. The conclusion was that the consumer did not have enough information about the technical details of the electric cars, their maintenance costs, the availability of mechanics and services, their amortisation, or the network of the charging points. However, if a consumer had any prior experience with the electric car, then there was a higher probability that he/she would have chosen it (MacInnis 2020). It shows that car dealers and governments need to inform the potential buyers about the electric car because they could enhance the demand for them this way.

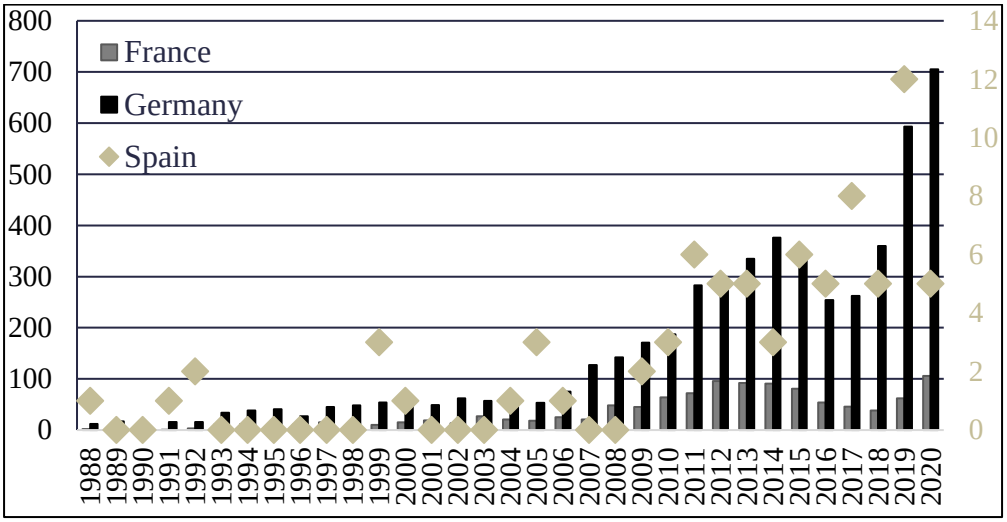
3. Patent overview of the electric car production in Germany, France, and Spain

Since the aim of the electric vehicle is to be climate-friendly, then the automotive industry and the related industries (like the energy sector) need various developments and innovations. Consumers prefer long battery life, low prices, quick charging times, and good charging infrastructure (Heymann 2020). Therefore, this study examined the patents that are linked to electric vehicles to see the innovations in the counties analysed.

More publications analysed the connection between patent and technology development, innovation, or R&D (for example, Baumann et al. 2021, Han et al. 2021, Lai et al. 2021, Lee et al. 2021, Ma–Porter 2015, Ma et al. 2014, Teichert–Ernst 1999). Our study built on an article that also analysed the patent of the electric car based on the "Electric propulsion with power supplied within the vehicle" category of the Espacenet (Pilkington et al. 2002). Its main consequence was that the significant patent-owning companies in the USA were Toyota, General Electric, and Mitsubishi.

To analyse the number of patents linked to electric cars, the Espacenet patent search database was used. Based on that database the users could search within the European Patent Office (EPO) information. In the advanced research, the "electric propulsion with power supplied within the vehicle" category was chosen (B60L50). We analysed the patent family instead of the publications. The webpage of the EPO defines it in the following way: "Set of interrelated patent applications filed in one or more countries to protect the same or a similar invention by a common inventor and linked by a common priority" (EPO 2021). The results included the classification of the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC) where the publication date of the family is between 01.01.1988 and 31.12.2020. One of the limits of this method was that the patent of electric cars could not be distinguished from the other electric vehicles, such as golf carts, electric bicycles, etc.

Figure 3 Patent numbers of the B60L50 category in France, Germany, and Spain between 1988 and 2020



Source: Self-created figure based on the (Espacenet 2021) dataset

Figure 3 presents the patent numbers of the "Electric propulsion with power supplied within the vehicle" category (Espacenet 2021). The left axis (black) shows the values of France and Germany, while the right axis (light gray) shows the values for Spain. As the previous section has shown, Germany is the leading automotive producer in Europe, consequently, this country owned the most patents in the integration. Based on the analysed patent category, Germany competed with Japan, the USA, and Korea. In 2020 Germany had the most B60L50 patent number globally. This fact shows how strong the German automotive industry focuses on the electric vehicle segment.

The period of the given German patents could be divided into two phases. The first phase was between 1988 and 2006 when its values were low. At that time the main focus of the industry was on vehicles with internal combustion and diesel engine, because their production was more effective and lower cost.

The second phase started in 2006 and ended in 2020, and it presented a dynamic growth in the patent numbers (except 2015 and 2016). One of its reasons could be that the German government supported the development of the electric car. The "Nationale Strategiekonferenz Elektromobilität" was announced at the end of 2008. It aimed to reach 1 million electric vehicles on the German roads by 2020. Next year a €500 million programme was started within the national Economic Stimulus Package II to accelerate the development and deployment of electric vehicles. That action mainly focused on technology and research.

The German government also founded the lithium-ion battery research programme (LIB 2015) with €60 million between 2008 and 2015 (European Parliament 2010). In 2010 the National Platform Electric Mobility (NPE) was announced, which brings together the main actors, that is, the manufacturers, the suppliers, politics, academia, the associations, unions, and society. Seven working groups were established to support the National Development Plan for Electric Mobility (European Parliament

2010). Therefore, the German automotive industry was characterized by a high level of interconnection, which could result in competitive advantages.

The German automotive industry concentrated on the development of electric vehicles, because if it could not keep up with its competitors like the USA, Japan, or China, then it could lose its lucrative positions on the market. As mentioned in the previous section, government incentives also played an important factor in the demand for electric vehicles, and more purchases were favourable for the manufacturers as well. The German studies also highlight the main role of the state subsidies (for example, in Scharf 2020, Klößner–Pfeifer 2015, Böckers et al. 2012, Höpfner et al. 2009).

The patent numbers analysed in France showed a tendency for a slow increase. The French government, like its German counterpart, also promoted the production of electric cars. For example, €400 million for R&D was announced on low-carbon vehicles between 2008 and 2012. That programme supported the development of vehicles as well as the infrastructure for charging. From 2009 a specific working group dealt with the installation of a charging network (European Parliament 2010). Because of Covid-19, the French President Emmanuel Macron has announced an €8 billion aid package to support the car industry. One of its aims is to make France a leading electric car manufacturer (RFI 2020).

The given patent numbers also followed an increasing tendency in Spain, however, the values were very low in comparison to France and Germany. The Spanish government announced various programs like MOVELE, and made more investments, but generally, those actions focused on the charging points and the purchase of electric cars (European Parliament 2010). The goal of the Integrated National Energy and Climate Plan 2021–2030 following the European Union's (EU's) energy and climate targets for 2030 is to achieve a fleet of 5 million electric vehicles on the Spanish roads with 500,000 chargers in 2030 (Congreso de Los Diputados 2019).

A common feature in the three countries analysed is the same main CPC subgroups, which were the following categories:

- Energy storage systems for electromobility, e.g. batteries (Y02T10/70);
- Electromobility specific charging systems or methods for batteries, ultra-capacitors, super capacitors or double-layer capacitors (Y02T10/7072);
- Electric energy management in electromobility (Y02T10/72);
- Energy storage using batteries (Y02E60/10);
- Electric machine technologies in electromobility (Y02T10/64).

Those developing areas are in line with consumer preferences. Based on the international survey by Deloitte (2021), German customers usually are concerned about the driving range (28%). The time required to charge (13%) was also highlighted after the lack of charging infrastructure (22%) and the cost/price premium (16%). The new technological improvements could also be good for the manufacturers because they could reduce their production costs.

Based on the database, the main applicants could be also collected from Germany, France, and Spain. As expected, most patents are tied to major European car manufacturers and their main suppliers. The competition between manufacturers and suppliers could stimulate development and productivity.

The Volkswagen Group had the most patent applications in Germany until 2020. It included Audi, and Porsche manufacturers as well. It is one of the main electric vehicle producers in 2020 (Auto-motor-und-sport.de 2020). Herbert Diess, the CEO of the Volkswagen Group announced that the company focused on electromobility with €30 billion in E-Offensive. Consequently, the group plans to launch more than 50 new electric vehicles by 2025, and every fourth car in the Group will be clean electric (VolkswagenAG 2021). On the other hand, the giga-factory of Tesla in Berlin is scheduled to start its production in early 2022. This announcement put great pressure on German manufacturers and further motivates them to make improvements.

Bosch was the main patent owner from the supplier category in Germany. The enterprise prepared for electromobility, because it assumed rapid growth in the years ahead (Bosch 2018). The data confirmed that assumption. Almost 40 percent of the sales revenue came from the electrical powertrain components in 2020 (Bosch 2021a). The company has built a great amount of capacity for power electronics, solid-state cells, and battery management (Bosch 2021b).

To see the reaction of the automotive suppliers to electro mobility in Germany Strina and Schmidt (2019) analyse 6 firms in South Westphalia. Their results show that the impact of electromobility is so far relatively low in the market. However, if the growth of e-vehicles continues to accelerate, the sales of companies in the exhaust / engine / transmission sector will decrease. An interesting consequence is that those companies that will be little affected by electromobility are already preparing for the change, mainly seeing opportunities in it, and already delivering for electric cars. But those suppliers that will be more affected by electromobility, tend to believe less that electric cars will prevail in the next 10 to 20 years, and try to optimize existing products for the combustion vehicle (Strina and Schmidt 2019).

In France, the most patent application is linked to the Renault Group. This is not surprising because the leading passenger electric vehicle model by fleet size in the European Union was the Renault Zoe, and was ahead of the Tesla Model 3 in 2020 based on the dataset of Statista (2021b). Most electric car buyers in France, Spain, and Germany too chose the Renault Zoe in 2020 (Best-selling-cars.com 2020b). In the "Renaulution" Strategy, the Renault Group (Renault, Dacia, Alpine and Mobilize) planned to launch 7 electric vehicles from the 14 new models by 2025 (Renaultgroup 2021).

Valeo was the supplier who had the most patent in France in the period analysed. The data has shown that the firm is innovative and tries to find new solutions. For example, in the Valeo catalogue in 2020, there were more than 13,000 new products and almost 60% of orders were for innovative products. Innovation means high investments, so Valeo spends more than €10 billion in technologies to reduce CO2 emissions (Valeo 2021).

In the case of Spain, the number of patents is really low. One of the reasons for this could be that even though Spain is a major vehicle manufacturer, its factories are owned by foreign investors. The main applicants were Charles Rippert and Franz Rueegg based on the dataset of Epsacenet. They have 4 patents each.

An interesting fact is that the list of the 50 biggest R&D inventors among companies in 2020 had significant representation from the automotive industry. Volkswagen was in 3rd place, Daimler 10th, but Toyota (12th), Ford (14th), BMW (17th), Bosch (19th), Nissan (37th), Renault (48th), and Peugeot (50th) also were on the

list (Petrov 2021). However, if we consider the most innovative companies in 2020, then we could also find the same companies, but their rankings are not as high there. For example, Volkswagen ranks 32nd in the most innovative companies. It improved six rankings over the previous year. Bosch as a new entrant was the 33rd (Colombus 2020). Therefore, those companies could move forward, however, they could not gain on Tesla, which was in 11th place (Colombus 2020).

4. Conclusion

The focus of this study has been to survey the patents in Germany, Spain, and France that have potential applications in the development of electric vehicles. The dataset showed an increase in new electric car registrations, although its proportion within all cars on the road is still rather low. The dynamic rise in demand was affected positively by the financial incentives of the governments. In addition to subsidies, other actions and tools will be needed to accelerate the spread of electric vehicles, because currently, their price is high in comparison to conventional cars. Furthermore, the potential owners do not have enough information about the financial benefits such as government subsidies and about technical details such as charging times and already available charging stations.

To reach a higher market penetration and climate-friendly characteristics, the electric car industry has to improve and innovate. The patent numbers have also been analysed in the three countries within the B60L50 category based on the dataset of the European Patent Office. The results have shown a dynamic growth in the patent numbers between 1988 and 2020. The purchase and production of electric cars were subsidized by the Spanish, German and French governments, as part of their climate strategy, which is part of "The European Green Deal", since the European Union is committed to reducing CO_2 emissions through increasing electric transportation.

Generally, most patent applications originated from the main automotive manufacturers within the countries analysed. The manufacturers are motivated to develop their electric vehicle technology, because of the regulations (e.g. CO_2 quotas), as well as the higher demand inspired by the financial incentives of the governments. Nevertheless, the competition and the leading position is also a powerful motivator because their main competitor, Tesla, is currently ranked higher in innovation. The American company not only uses new technologies but also applies other management and marketing tools.

Further research areas could be the analysis of the electric car market with a global, or a European Union perspective. In addition, the strategies of the electric car makers and their main suppliers also could be examined. On the other hand, the consumer attitude could be analysed with questionnaires to see the acceptance of electric cars or the main influencing factors of the demand. To repeat the questionnaire survey also could be a research direction, because that shows how the attitude of the people changes during a given period.

5. Future Work

Based on the patent information that has been presented in this study, a deeper analysis could be carried out that would highlight the main directions of each of the research areas presented in the patent survey within this study, in order to show its relevance towards the development of electric vehicles.

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