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IMPACT OF MACROECONOMIC STABILITY ON AUTOMOBILE SALES IN THE EUROPEAN MARKET

Master thesis

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Master thesis

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ABSTRACT

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The final thesis aims to analyse the impact of macroeconomic stability on Automobile Sales in the European market. This includes the overall analysis of the industry and definition of main macroeconomic indicators based on econometric modelling. The work is divided into 3 chapters. It contains 44 figures, 16 tables, 17 formulas and 6 annexes. The first chapter is dedicated to the literature review and general overview of the automobile industry from the points of the final consumer and manufacturer. The second part provides the methodology connected with models that are going to be used in further analysis. The final chapter deals with a panel data model with fixed effects, cluster analysis and neural networking in terms of selected countries and manufacturers. The result of this work confirms the strong impact of macroeconomic stability on automobile sales in Europe. The analysis of chosen countries and producers demonstrates additional patterns and specific characteristics connected with the particular companies. Also, the analysis describes the European automobile market with all main tendencies and regulation.

Keywords: automotive industry, passenger vehicle sales, Europe, macroeconomic stability, panel data, cluster analysis, cointegration, demand, automotive producers.

Content

INTRODUCTION

Competition among automobile manufacturers continues to grow that creates additional demand for new advanced strategies to make business processes more efficient. According to long product development cycles, effective production planning of automobiles requires accurate forecasting of long-term (6–24 months) sales and demand. This proves the necessity to understand all possible factors that influence the total number of sales. Moreover, the presented in the thesis overview of the automotive industry in Europe and possible econometric tools for the analysis are crucial and useful to understand, analyse and make some predictions for the future development of whole industry.

Ones of the most important are macroeconomic stability of the region, the ability to produce and buy new passenger cars. All regions around the world differ by specific characteristics, however, there some important market indicators that influence sales in the same way. Since Europe is the initial region of the analysis, it is important to analyse how final consumers and main vehicle producers react in response to changings of the main macroeconomic indicators.

Additionally, in the master thesis, there is an overview of the automotive market in Europe with all main producers and sellers in the region. The number of sales also depends on the European or other countries regulations, trade wars, environmental requirements and simple preferences of the local residents. As a result, all this not financial factors are needed to be investigated as well.

Moreover, this study can be useful not only for the particular companies that are able to implement econometric modelling, but for all players on the market who are interested in the main tendencies, challenges and overall performance of the industry in general. That, in turn, will increase the total level of the competition on the market that will stimulate to make operational activities more efficient.

Every research connected with data analysis and is useful for every company on the market. In this case, the modelling is one of the most crucial elements, that is able to confirm or refute every theoretical hypothesis and define the unexpectable connection between some indicators. This can help to analyse the whole picture of the market and can allow making the right strategic decisions in the most important time.

Overall, automobile sales analysis and forecasting was under careful scrutiny during the past 30 years in papers of Armstrong (2000), Berkovec (1985), Franses (1994), Greenspan and Cohen (1999), Hulsmann (2011), Lave and Train (1979), Mannering and Train (1985), who have modelled and forecasted automotive demand and sales in different countries using a variety of econometric tools. Currently, numerous academics continue to analyse the automotive industry to explain main patterns and be able to forecast in the most precise way.

In this master thesis the panel data model is implemented to analyses global influence on the European market. It is also used for clustering of European countries and automotive producers due to levels of macroeconomic stability' influence. This will help to identify some regions and groups of manufacturers with different strategies for sales forecasting that should be used.

The main **goal** is to analyse the automotive market in European countries from different points of view and define main macroeconomic indicators based on econometric modelling. To achieve the specified goal there are particular **tasks** are needed to be solved:

- Define the importance of the automotive industry in the European economy;
- Analyse profits of main European automotive producer in comparison with competitors around the world;
- Explore the new environmental regulations and their effect on the automotive industry;
- Investigate the R&D spendings of European companies;
- Review the main risks connected with the industry;
- Explore the differences in the financial capacity of European residents;
- Analyse the main automotive producers on the selected market;
- Look into production and consumption of passenger vehicles by country;
- Confirm the importance of the industry in terms of available workplaces;
- Define the two most popular models for further analysis;
- Analyse the performances of selected countries in terms of vehicle sales;
- Define the best-performed region and confirm the influence of the selected macroeconomic indicators;
- Define the influence of selected indicators on main automotive producers;
- Use cluster analysis to group the selected producers and chose the best performing group;
- Check the basic theoretical assumption of the influence of the indicators.

The main **object** of the master thesis is the automotive market in Europe. The main **subject** is the influence of macroeconomic indicators on the final number of passenger vehicle sells in European countries.

According to the defined goal and listed tasks, the thesis consists of three sections. In the first one, the literature review, the general overview of the automotive industry from the point of final consumer and producer are presented. Also, the main non-financial indicators that influence the number of sells, are investigated. Moreover, the main tendencies, regulation and future challenges are described as well. The second section consists of the methodology that is going to be used in further analysis and in modelling. The separate attention is to all assumption that must be fulfilled to be able to interpret the constructed models. In the third section, panel data model with fixed effects, cluster analysis, SOM techniques with neural networking are performed to define the group with the best results to make interpretation and analysis of investigated countries and companies. For this purpose, *MatLab, RStudio* and *Gretl* are used.

To sum up, the core idea of the master thesis is to present a possible methodology that can be used to improve production processes and to predict future sales according to the analysis of macroeconomic stability in particular countries. Additionally, this analysis is performed considering the overall performance of the industry with all main players and other non-financial factors like political uncertainty, trade wars, tariffs, innovations and environmental regulations.

1. Current state of the automotive industry in Europe

In this section, the general literature review is presented to determine the most appropriate macroeconomic indicators that have been used in studies before. Also based on the review it is possible to determine the most frequent econometric techniques are used during such analysis. Moreover, this literature can be useful in terms to collect relevant data from the official databases. In this section, the analysis of the automotive market in the European region is presented that includes historical specificities of the region, main regulations processes, current trends, differences among the countries in the region and main threats and challenges are going to be in the future. Finally, the relevant information about all passenger cars producers that sell vehicles in the European region is analysed to be able to interpret all results of further econometric models.

1.1. Literature Review

Past researches and analysis of the influence of the macroeconomic indicators on the total number of passenger car sales are limited and are mostly focused on ASEAN or North America countries. Based on the review of these searches several important factors are going to be defined to be able to proceed with the necessary analysis.

Generally, automobile sales forecasting has received notable attention in the past 30 years in papers of Armstrong (2000), Berkovec (1985), Franses (1994), Greenspan and Cohen (1999), Hulsmann (2012), Lave and Train (1979), Mannering and Train (1985), who modelled and forecasted automotive demand or sales in different countries using econometric tools such as regression models. Moreover, a lot of attention in researches is given to factors such as advertising, sales promotions, retail prices, and technological sophistication like in the paper of Landwehr (2011). However, the main purpose of this master thesis is to analyse the current conditions of the European automotive industry with all possible tendencies and challenges and to determine the impact of macroeconomic stability on automobile sales in the region.

This topic has been already investigated by some researches in different regions around the world. For instance, Konstantinos N. Konstantakisa, Christina Miliotia, Panayotis G. Michaelides (2017) have used a Vector Autoregressive (VAR) model to prove the influence of existing social, financial and political conditions of the local economy in Greece on automotive demand and temporary medium-run influence of the various shocks on car sales during last financial crisis period. Also, HolmDetlev Köhler (2012) has analysed the relation between macroeconomic stability and automotive sales in response to the financial crises in Spain started in 2007. Fidlizan Muhammad, Mohd Yahya Mohd Hussin, Azila Abdul Razak, Norimah Rambeli, Gan Pei Tha (2013) with the same method have determined significant impact only of IPI variable in short-time among all other macroeconomic variables in a short and long time for 2004-2010 years in Malaysia.

At the same time, OLS regression models of the highest automobile production countries proceeded by Ferhat Pehlivanoglu and Retno Riyanti (2018), have demonstrated a positive impact of real GDP, car production, gasoline price on a total number of sales. While the change in GDP per capita, inflation and exchange rate have demonstrated the opposite effect on sales.

Moreover, to fully analyse the impact on the automotive industry, it is necessary to examine some additional variables and methods. For instance, the analysis of the particular company Skoda Auto made by Ondrej Sezemsky (2014) with regression and VAR models has determined the negative influence of exchange rate and S&P100 index on Skoda Auto sales for 2000-2014 years. Albert L. Danielsen and Jimmy E. Hilliard (1983) have started to prove the relationship between oil prices and new car sales in the United States using regression methodology. Moreover, Akkarapol Sangasoongsong, Satish T.S. Bukkapatnam, Jaebeom Kimb, Parameshwaran S. Iyer and R.P. Suresh (2012) have used a vector error correlation model for such analysis to be able to indicate the long-run effect of chosen economic indicators and use a feedback system approach in estimating the market response. This model has been used in the analysis of the American market during the period from 1975 to 2010 based on monthly data.

Further analysis of the scientific literature can be presented in the following table that summaries main macroeconomic indicators that influence automotive production and demand (Gaspareniene, 2016).

Table 1.1. Main macroeconomic factors determined by researchers

The factors influence automobile production		**The factors influence automobile demand**	
Factor	Author(s)	Factor	Author(s)
GDP	Madlani, Ulvestad, 2012; Haugh, et. al., 2010	GDP	Muhammad, et. al., 2013; Ding, Akoorie, 2013; Pehlivanoglu, Riyanti, 2018

Table 1.1. Main macroeconomic factors determined by researchers (continued)

Governmental policy	Madlani, Ulvestad, 2012; Drauz, 2013	GDP per capita	Haugh, et. al., 2010; APEC Automotive Dialogue, 2002
Exchange rate	Madlani, Ulvestad, 2012; Drauz, 2013	Fuel prices	Muhammad, et. al., 2012; Busse, et. al., 2009; Pehlivanoglu, Riyanti, 2018; Danielsen, Hilliard, 1983
Price of raw materials	Madlani, Ulvestad, 2012; Ford Motor Company, 2012	Interest rate	Muhammad, et. al., 2012; Haugh, et. al., 2010; Erdem, Nazlioglu, 2013
Petroleum price	Ford Motor Company, 2012, Kumar, Maheswaran, 2013	Unemployment rate	Muhammad, et. al., 2012
Interest rate	Ford Motor Company, 2012	Income level	Dargay, 2001; Smusin, Makayeva, 2009
Public debt	Ford Motor Company, 2012	Inflation	Muhammad, et. al., 2012; APEC Automotive Dialogue, 2002
Demand	European Commission, 2008	Private sector consumption	Haugh, et. al., 2010
		Petroleum price	Haugh, et. al., 2010, Abu-Eisheh, Mannering, 2002
		Financial state of the markets	Haugh, et. al., 2010, Ding, Akoorie, 2013
		Customers' certainty about the future	Haugh, et. al., 2010, APEC Automotive Dialogue, 2002
		Customers' priorities	Erdem, Nazlioglu, 2013
		International trade	Erdem, Nazlioglu, 2013
		Manufacturing	Erdem, Nazlioglu, 2013; Smusin, Makayeva, 2009; Pehlivanoglu, Riyanti, 2018
		Exchange rate	Ludvigson, 1998; APEC Automotive Dialogue, 2002
Source: self-proceeded based on Gaspareniene, 2014		Real estate price	Smusin, Makayeva, 2009

As a result, it is possible to summarise that gross domestic product, inflation, unemployment rate, loan rate, oil prices, exchange rates and some stock indexes are often used to represent general economic conditions for some countries and to analyse the influence on sales, what is a fundamental part of the industry development.

In addition to scientific literature, there are a variety of Associations that collect and analyse all relevant data connected with the industry and lobby the most crucial interests of the producers. European Automobile Manufacturers Association is an example of such an organisation in the European Union that was established in 1972 and consists of all the biggest manufacturers in Europe. Currently, it is connected with 73% of vehicle producers in the European Union and 62% in the European region.

Moreover, since the automotive industry is one of the main components of national economies every region or country has own departments and researches connected with the industry. They provide a variety of relative documents, analysis and related information to the automotive market in the specific region and worldwide. All statistical data are presented on the Eurostat and World Bank databases can be used for the collection of the necessary data to perform further analysis.

The main tendencies, future challenges and transformations on the automotive market are under additional attention of Big 4 companies that usually are the independent auditors for multinational automotive corporations.

1.2. Overview of the automotive market in Europe

During the last century, the automotive industry became one of the main components of many national economies. Regarding other goods cars significantly increase the shape and currently are one of the important components for every household. Moreover, the automotive industry accounts for almost 14 million jobs only in European Union countries (EUROSTAT). At the same time, the market is still developing and continue to implement innovative solutions to attract more consumers and to be more competitive in response to fast-growing BRIC and North America markets.

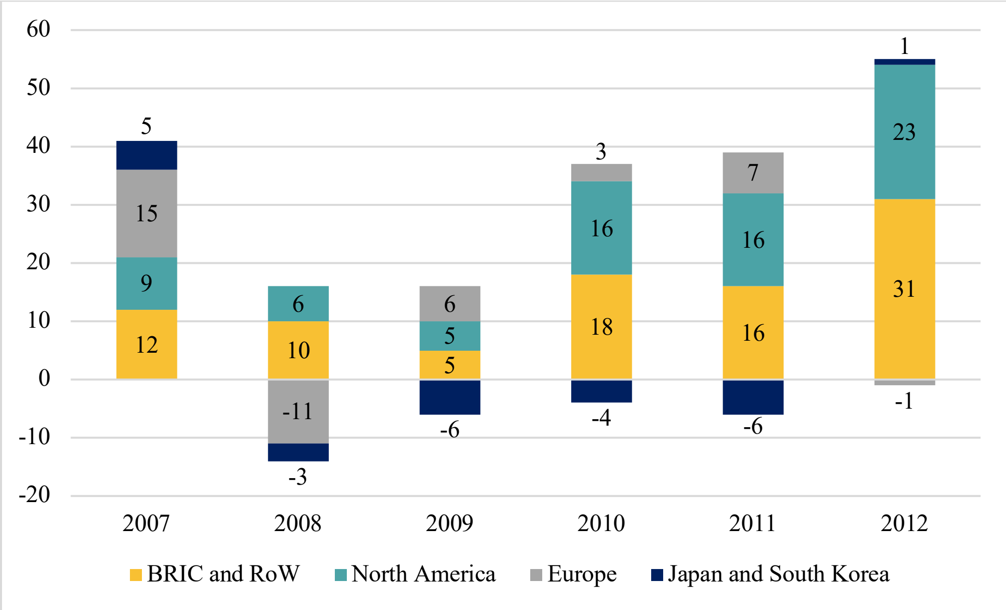
Table 1.2. EU automotive employment

	2013	**2014**	**2015**	**2016**	**2017**	**% change 17/16**
Manufacturing direct	2 291 594	2 369 570	2 451 219	2 503 658	2 607 477	4.1
Manufacturing indirect	811 344	818 630	890 110	882 627	887 350	0.5
Automobile use	4 261 539	4 256 382	4 303 637	4 448 071	4 525 639	1.7
Transport	4 335 551	4 450 654	4 633 609	5 120 469	5 147 575	0.5
Construction	591 269	607 908	647 600	621 334	625 658	0.7
Total	**12 291 297**	**12 503 144**	**12 926 175**	**13 576 158**	**13 793 699**	**1.6**

Source: self-proceed based on EUROSTAT

Overall, the global automotive market gradually develops and total profits and sales increases. The biggest recession was in 2008-2009 because of the global financial crisis. However, during followed 10 years the industry regenerated. For example, global passenger car profit renewed its pre-crisis level in 2011 that is demonstrated in the following graph.

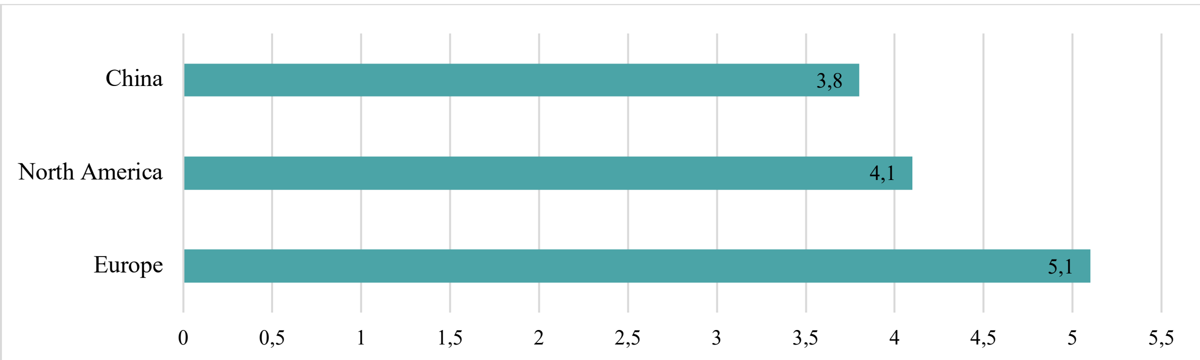
Figure 1.1. Automotive profits before and after global financial crisis 2008 by geography in EUR billions



Source: self-proceed based on EUROSTAT

According to the prognosis in previous years, the global profits of the industry in 2020 will increase up to EUR 79 billion that is almost 50% of increase based on the 2012 year. However, according to the COVID-19 in China and other countries, the projected value can significantly decrease. Some researchers predict the average decline by 4 per cent worldwide, however, this amount can be even higher in case the biggest automotive manufactures close. Based on the predictions of Statista Dossier, sales of passenger cars are going to decrease to 59.5 million units in comparison with the peak of 79.6 million in 2017. The main reason is the closing of main Chinese automotive factories in Wuhan, Europe and North America. Also, nationwide outbreaks and lockdowns negatively impact on the people possibility to buy a new car.

Figure 1.2. Estimated reduction in production in response to COVID-19, by region in %

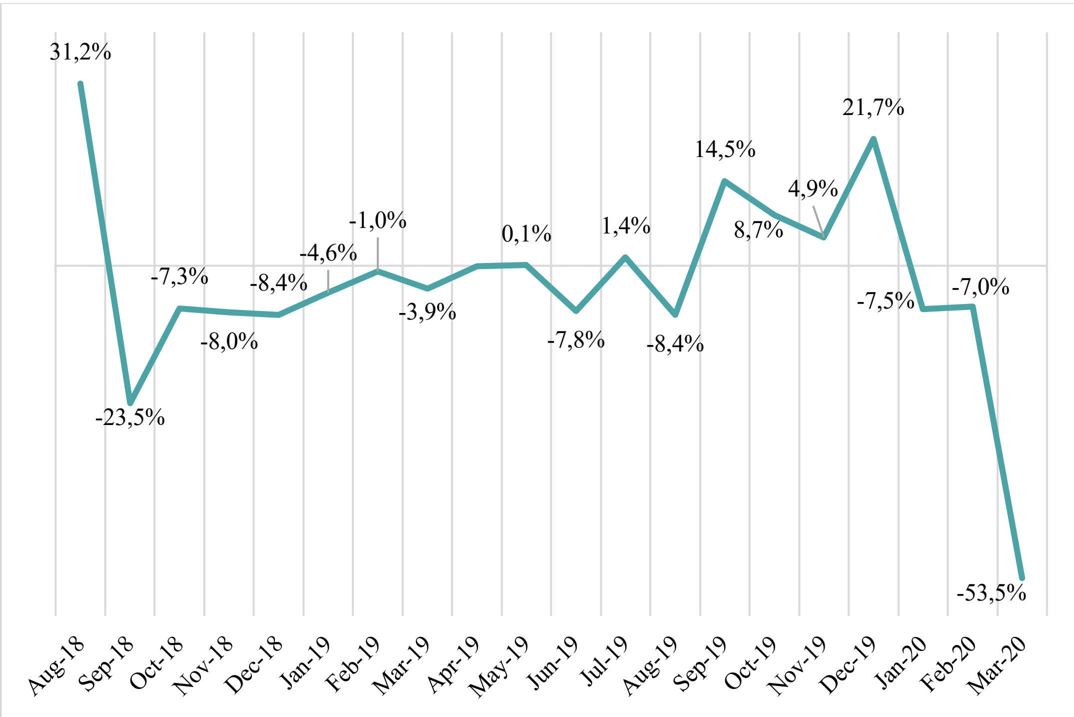


Source: STATISTA, published by I. Wagner, 2020

Additionally, the second important issue presented in Figure 1.1 is a negative profit of European companies in 2012. During investigated 5 years BRIC countries and North America increased profits and sales worldwide, however, Europe went in the other direction. Before the global financial crisis European producers had demonstrated the biggest profits in comparison to other automotive producers, when in 2012 only they declared losses of EUR 1 million. The main explanation of this is in two main reasons that are typical for the European market. First of all, the number of new consumers continue to decrease and the level of new registration of vehicles significantly decrease. Secondly, Europe has a well-developed automotive market with a high level of competition that decreases final prices for customers and total revenue from sales of manufactures.

The same tendency was in 2019 when total demand in European countries decreased by 3.1% in comparison with the previous year, counting only 8.2 million registrations in the first half of the year. Moreover, the Central European countries currently are the main driver for automotive demand. During the first half of 2019, Western Europe countries in total demonstrated 3.5% of decreasing of registrations while Central European declared 1.4% of growth.

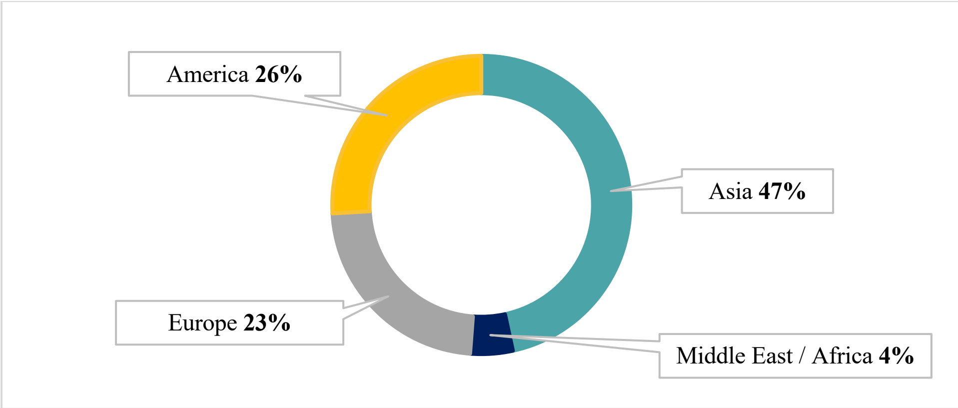
Figure 1.3. Change in new passenger car registrations in UK and EU markets in %



Source: STATISTA, published by I. Wagner, 2020

The next picture demonstrates that in 2018 Europe had 22.9% of the total share in new passenger car registration.

Figure 1.4. Share in new passenger car registration by region in 2018



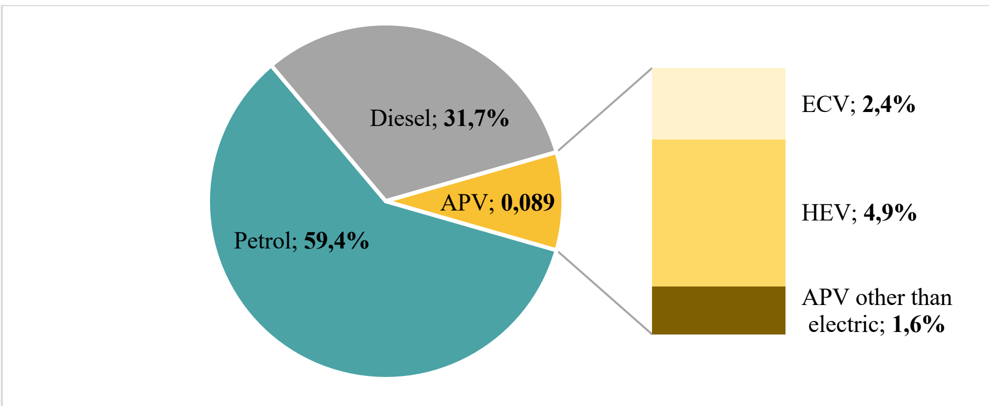
Source: self-proceed based on ACEA, IHS MARKIT

The biggest amounts of new car registrations were in Luxembourg, Belgium, Germany and Austria. The lowest results were in Bulgaria, Romania and Latvia. In average, the European Union had 30 new cars per 1 000 residents in 2018. Moreover, 35% of these vehicles were sport utility vehicles, 29% - a small (A+B) type, and 19% - a lower medium (C) type.

In average, the European Union has 602 cars per 1 000 inhabitants according to the data from 2017. The highest motorisation rates are in Luxembourg, Cyprus, Italy and Malta, while Romania, Latvia, Hungary and Croatia have 400 vehicles per 1 000 inhabitants on average.

Currently, the European market is presented by 59.4% of petrol vehicles and 31.7% of diesel. During the first half of 2019, only 8.9% of new cars were alternatively powered. In dynamics, the demand for petrol cars is increasing around the European region, except for Germany. The highest percentage of growth was declared in Italy and Central Europe countries.

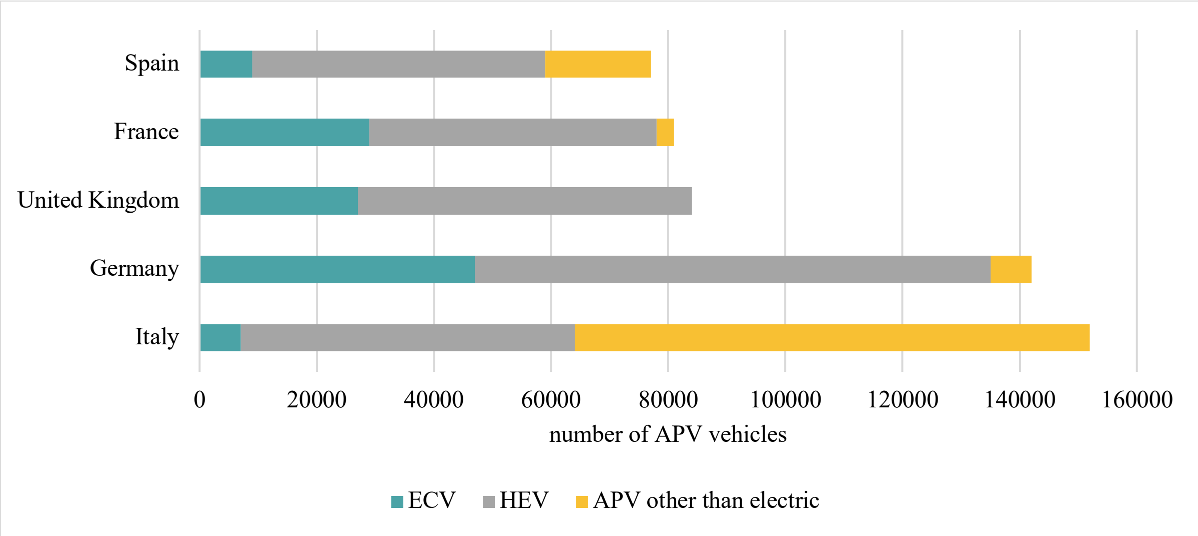
Figure 1.5. Shares in new car registration by fuel type in H1 2018



Source: self-proceed based on ACEA

In terms of alternatively powered vehicles, there is a significant increase during the last years with a total level of 27.5% in 2019. Sales of electric cars represent up to 40% of total APV and were doubled in amount during last year, while the number of hybrids was declined by almost 7%. Remarkable, Western Europe countries are the main drivers of this growth.

Figure 1.6. Alternatively powered car registrations in the 5 key EU markets in H1 2019



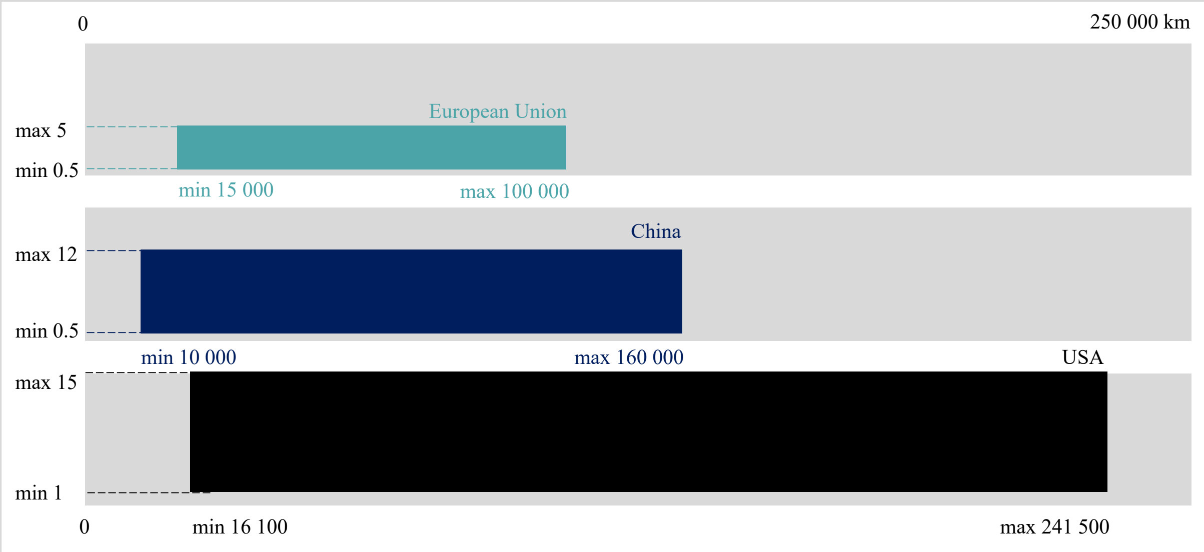
Source: European Automobile Manufacturers Association, 2019

Moreover, the European automotive industry is currently one of the most regulated industries in the region. There are various regulations relating to safety, taxation, the environment that have a significant impact on manufacturing spending. According to the McKinsey study in 1998-2011 regulatory improvements such as airbags, ESP, fuel efficiency and weight reduction caused the increase in production costs by 3-4 per cent per year. At the same time, recent regulations are going to increase total spending by 16% in 2020. However, in response to all changings in costs, the manufactures can't final price to customers because of a high level of competition on the market. As a result, price increasing is caused only by inflation in the European countries.

Another important topic that connected to the previous is ecological initiatives between many countries. The best example is the Paris Agreement when some countries signed the global initiative to decrease the total level of emission and control new models to respond agreed eco standards. As a result, the majority of automotive producers started to spend a lot of funds on R&D to construct eco-friendly cars. This initiated the formation of the innovative electric mobility sector. Main mass producers started to implement electric battery and other technologies to reduce or prevent any pollution.

Besides, particular cities and countries started to implement additional restriction for personal use, for import of new vehicles and to enter different zones in big cities.

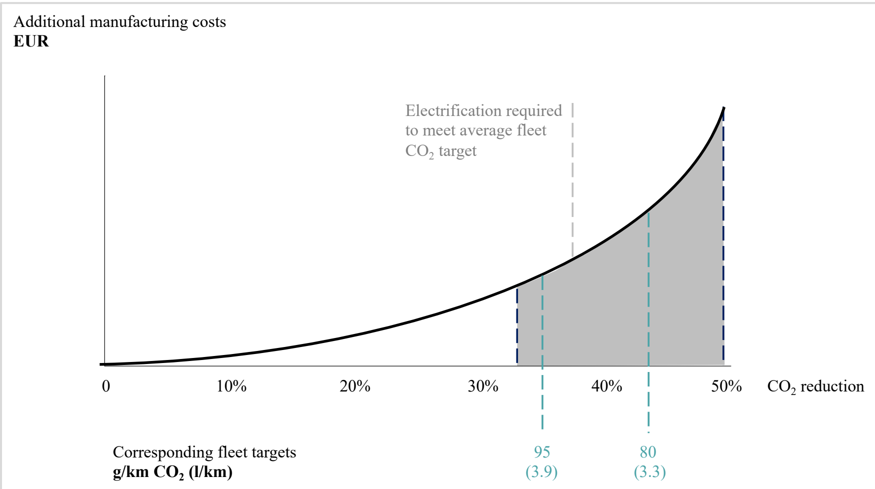
Figure 1.7. Passenger cars in-service conformity testing requirements in selected countries in 2019



Source: The International council on Clean Transportation, 2019

Carbon dioxide regulation is used not only in European countries that increase the costs of every car producer around the world.

Figure 1.8. Tougher emissions regulations

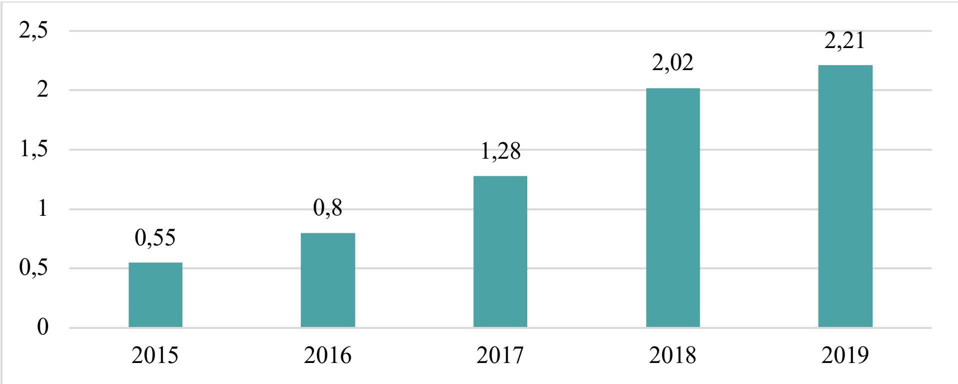


Source: ICTT and McKinsey

From the picture above more efforts to reduce emission cause more additional manufacturing costs associated with this. However, there is a possibility to decrease such costs and investments connected with it. The major players on the market can create some strategic alliances to develop new technologies together in response to all current and future government regulations. Fully electro cars have a lot of restriction for now and can't substitute the traditional ones immediately.

From the Figure 1.9. it is possible to notice a strong tendency of increasing in plug-in electric light vehicle sales worldwide from 2015 to 2019. In 2019 near 2.2 million electric cars were sold despite the decreasing in Chinese sales in 2018.

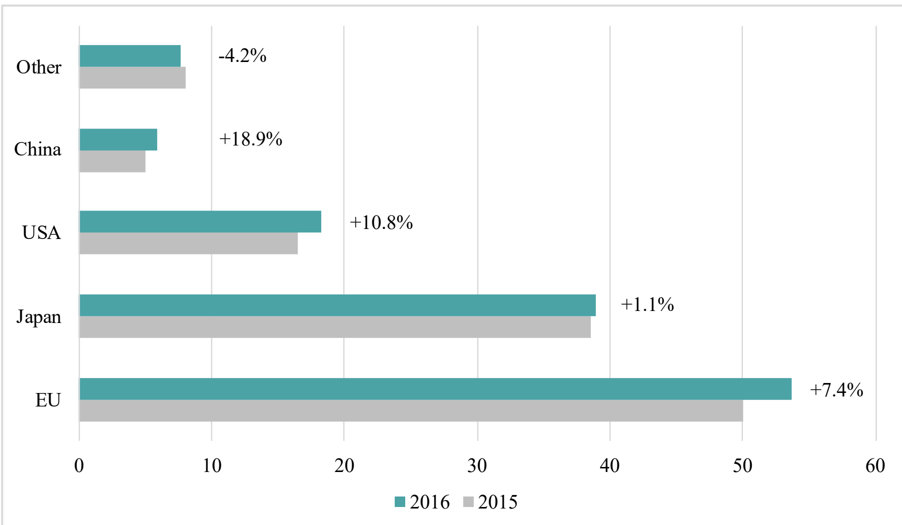
Figure 1.9. Global plug-in electric light vehicle sales in million units



Source: STATISTA, published by I. Wagner, 2020

In addition to the issue of carbon emission described above, manufactures spend a lot of recourses on other projects and programs. According to the European Automobile Manufacturers Association the EU is the biggest world investor in automotive industry in terms of R&D that equal to 28% of their total spending. Moreover, automotive industry in Europe is responsible for 54% of total R&D investments in the region (ACEA Pocket Guide 2018 – 2019).

Figure 1.10. World investors in automotive R&D



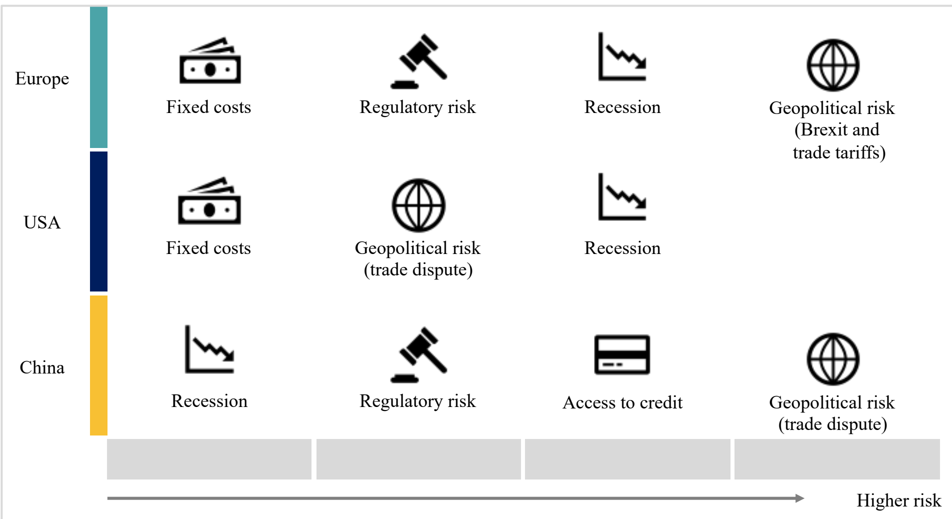
Source: ACEA, 2018

Based on the results of the DRIVES Project report D2.9. the factories mostly spend on big data that refers to collecting and processing of all connected data to be able to respond to all main changes and tendencies on the market. based on the recent surveys the most important parts of such investments cybersecurity and privacy are. Advanced Driver-Assistance systems are the second biggest component of R&D spending of European manufactures based on the levels of driving automation developed by European Parliamentary Research Service (EPRS). The next important component of the investments is Artifactual Intelligence actively implemented by big automotive producers to forecast future sales and respond to all market challenges. Other costs are distributed to supply chain solutions, sharing and electrification that was mentioned above.

In EUR million the European Union has a positive trade balance and in 2018 it was equal to 81 596 million with export that is in almost 3 times bigger than import. The biggest export market is Asia and Oceania that amounts 36.2% of the EU export. North America is the second-biggest export market and has almost 32% of the total amount. EFTA and Eastern Europe have around 20% and hold third place in automotive export from the European Union countries. Middle East, Africa and Central, South America have 5.5%, 5.4% and 2.3% respectively. In terms of countries, the biggest importers of the EU vehicles are United States, China, Japan and Switzerland.

On the following picture, the main risks for three main markets are presented. Europe and China have a higher geopolitical risk according to recent Brexit, trade tariffs in the EU and trade disputes and wars in China. Recession is more likely to be on European and North America markets.

Figure 1.11. Possible risks by region in 2019



Source: S&P Global Ratings

Moreover, recent trade conflicts are observed not only between China and the United States but include the United States - Europe, and the United Kingdom – European Union relations.

Considering the size and quantity of countries in the European region the enormous difference between regions and countries are presented on the market. For instance, even the European Union with 370 million residents that is the biggest market bloc in the world has a variety of programs to decrease current gaps between countries. Alongside common European institutions, policies, regulations and free trade agreement the region is described by a high level of diversity that influences market demand and supply.

The main explanation of these differences is in people tastes, culture and other social characteristics. However, socioeconomic conditions of a particular country or region have an enormous impact as well (Williams, 2002). The last European policies aim to achieve some level of socioeconomic harmonisation between regions however according to the latest data this goal is not reached. The problem becomes more complex and complicated in response to new members that recently joined the European Union and European free trade agreement. Moreover, countries that are not in the European Union, for now, are still a part of European automotive market are characterised by lower economic performance, worse national economies and lower purchasing power of the residents.

Table 1.3. Actual individual consumption per capita in purchasing power standards in selected countries in 2018 (EU-28 = 100)

BE	BG	DE	EL	ES	FR	LU	NL	PL	SK	SE	AL	BA
113	56	120	77	90	107	134	113	76	73	108	39	41

Source: Eurostat, 2019

The table above confirms the differences by countries in the European Union and demonstrates big gaps between the Northern and the Southern European countries.

In addition to Purchasing Power, the macroeconomic factors that influence on the automotive industry can be divided into two groups: that has an impact on automotive production and the ones that influence automotive demand. Based on the research and report of Madlani, Ulvestad in 2012, Drauz in 2013 and Ford Motor Company analysis in 2012 and European Commission report in 2008 the main macroeconomic factors of the first group are GDP, governmental policy, exchange rate, price of raw materials, petroleum price, interest rate and demand. The second group consists of GDP per capita, fuel prices, unemployment rate, inflation, income level, exchange rate and real estate price.

Overall, the European market can be described by three main particularities in comparison to the global market. First of all, there is a fundament distinction in contrast to North America in the average amount of cars per customer. Statistically, every American household has in average 2.5 vehicles while every European one has only one car on average. Therefore, on average Americans change the car in 2.5 times more frequently in comparison to Europeans. Secondly, sport and luxury cars are mostly produced in Europe but are sold over the world. Europe is a lead market in terms of innovations and luxury that can be explained by the higher level of R&D expenses. Based on the analysis by Pinch in 1997 and Henry in 2000, Europe is the center of world design and assembly of sports cars (Ulrich, 2003). Finally, common European regulations and policies help to shape and deepen consumer preferences.

To sum up the importance of the automotive industry in Europe, it is worth to determine its main distribution components. Firstly, the industry is one of the biggest contributors to value-added and accounts for about 3% of GDP and 7% of the EU's total manufacturing. Also, some countries are so dependent on the automotive industry and have more than 50% of GDP related to automotive production. Secondly, as was mentioned above, the automotive market is a workplace for more than 14 millions of people that directly and indirectly connected to the industry. Also, additional jobs can be created in terms of high investments in research and development by big European manufactures. Thirdly, the automotive industry in Europe is the biggest investor in R&D in comparison with other markets around the world and is the major investor among other sectors in the European Union. Majority of automotive patterns and innovative solutions are created and registered in Europe. This signs that the industry is a future-oriented and will have a strong competitive position in the future. Also, in comparison to other big sectors in Europe such as mining, chemicals, paper, oil refining and basic metals the automotive industry has the high level of investment in fixed capital, plant and other fixed assets. Moreover, as one of the biggest sources of fiscal revenue in European countries, the industry represents more than 8% in average of total national revenues in European countries. Finally, it is a stable contributor to trade and represents around 5% of the total EU export.

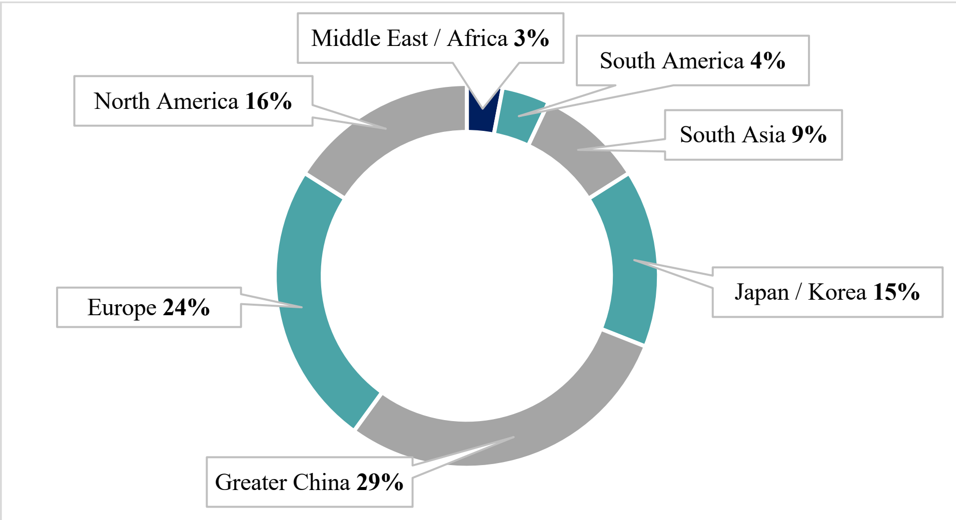
However, the European market is more sensitive to changes in macroeconomic indicators that influence of production costs of manufactories and total demand that are crucial to generate profit. Additional environmental initiatives, regulations and a high level of competitiveness on the market cause additional challenges to the main players on the market.

1.3. Main automotive manufactures and overview of the car production in Europe

One of the main points of this research is the sensitivity of main automotive producers in Europe and their response to changing of main macroeconomic indicators. As was mentioned earlier, the total demand for new cars is one of the main components that influence sales.

Europe is one of the biggest automotive producers and has around 24% of global share after China with 29% of total automotive sales worldwide.

Figure 1.12. World passenger vehicle production by region in 2018

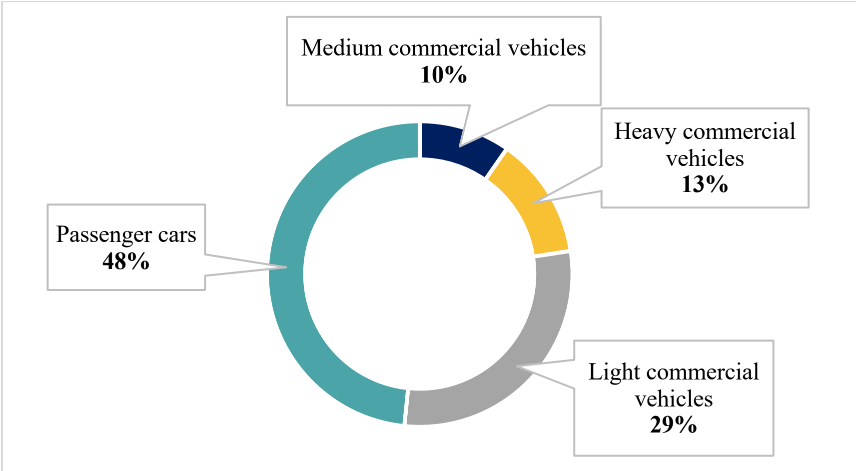


Source: IHS MARKIT, OICA

Central Europe countries demonstrated one of the most significant growth in the automotive industry during the last years. After global financial crises in 2008 Visegrad countries received FDI that allowed to reconstruct the whole economy after socialism and create a powerful automotive sector. That is why this industry became one of the most important manufacturing in these countries and combined high capital, technology and skilled labour. Slovakia and the Czech Republic are one of the leaders in car production per capita over the world and in 2012 ranked first and second respectively. The two reasons for such success are the geographic location and enough of skilled, cheap, and docile labour.

The European market is mostly concentrated on passenger cars that have 86.1% of total production in the region. Light commercial vehicles have 11.1%, heavy and medium commercial cars have 2.2% and 0.6% respectively.

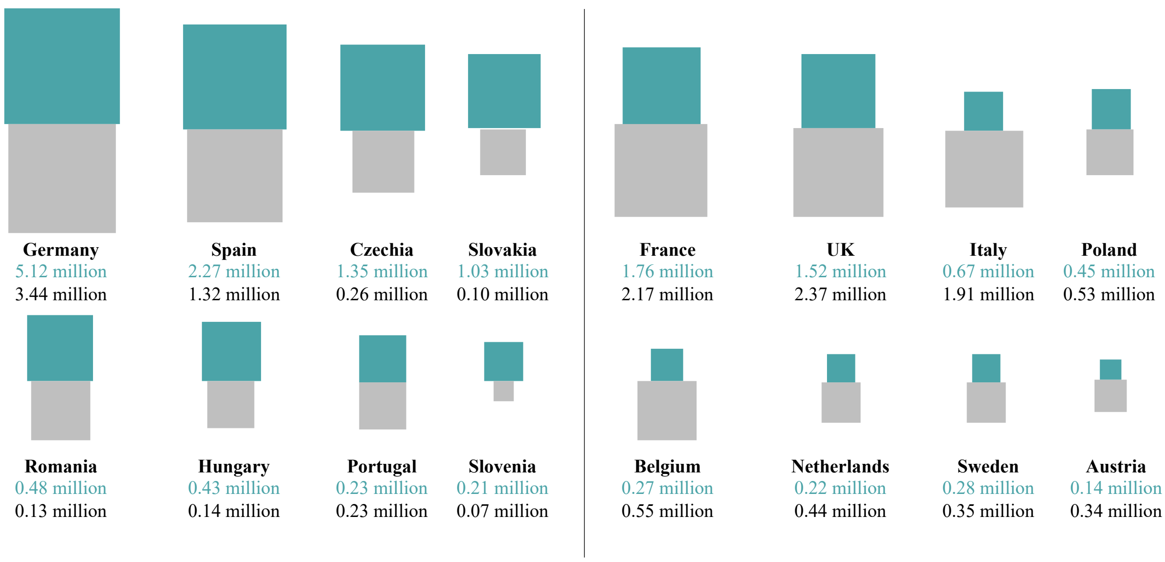
Figure 1.13. EU vehicle production by type in 2018



Source: IHS MARKIT, OICA

Germany is still the biggest manufacturer of automotive vehicles and has the highest number of new passenger car registration. Also, Germany export one of the highest fractions of produced cars into other European countries and around the world that was equal to 5.12 million in 2018. The similar situation is with Spain that is the second-biggest producer in the region and exported more than 2 million during the same year. At the same time, Slovakia that is the largest vehicle producer per capita produces up to 10 times more than registers within the country. However, countries like France, the United Kingdom and Italy have a reverse tendency and consume more passenger cars than produce.

Figure 1.14. New passenger car registration and production by country in 2018



Source: European Automobile Manufacturers Association, 2019

In the following table, top-selling passenger car models in EU-28 represents 17.5% of total sales in the region. German VW had the biggest market share in sales in 2018 and was represented by VW Golf, VW Polo and VW Tiguan. At the same time, French Renault Clio and American Ford Fiesta also demonstrated a high level of sales equal to 2.2% and 1.8% respectively.

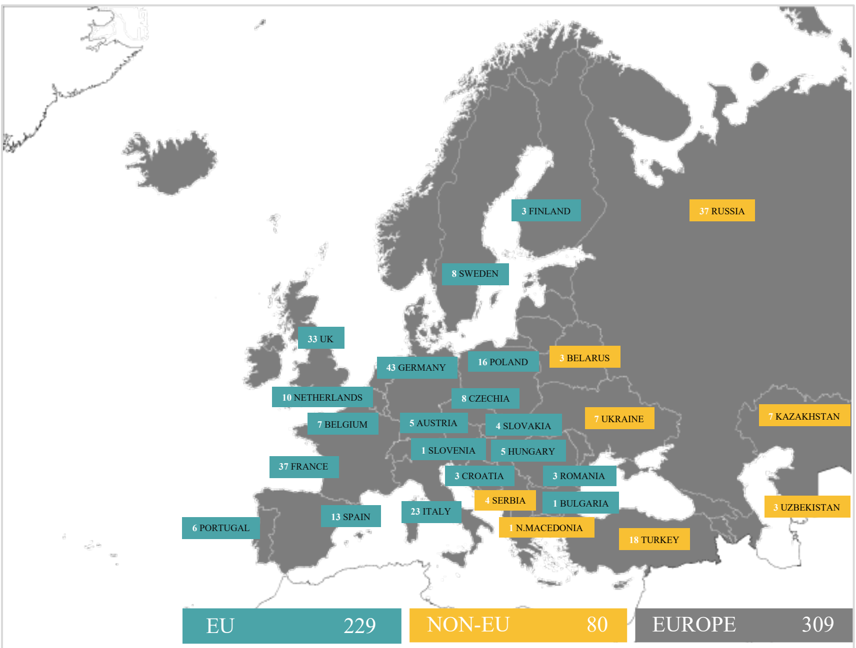
Table 1.4. Top-selling passenger cars in EU-28

Model	Sales number	Market share, %
VW Golf	425 308	2.8
Renault Clio	329 897	2.2
VW Polo	292 543	1.9
Ford Fiesta	266 959	1.8
VW Tiguan	242 598	1.6
Nissan Quashqai	230 649	1.5
Peugeot 207	226 394	1.5
Toyota Yaris	211 109	1.4
Renault Captur	208 953	1.4
Dacia Sandero	207 406	1.4

Source: International Council of Clean Transportation

The biggest amount of automobile assembly and engine production plans are located in Germany with a total number of 43. The total number of such factories in the European region is 229 including 229 in the European Union, 7 in Ukraine, 3 in Belarus, 4 in Serbia and 1 in North Macedonia.

Figure 1.15. Automobile assembly and engine production plants in Europe



Source: European Automobile Manufacturers Association, 2019

These plans directly employed 2 607 477 employees in 2017 according to Eurostat. The higher number of workers is in Germany with 869 118 places and the smallest – in Cyprus. France, Poland, Czech Republic and the United Kingdom have around 200 000 workplaces directly connected with the automotive industry.

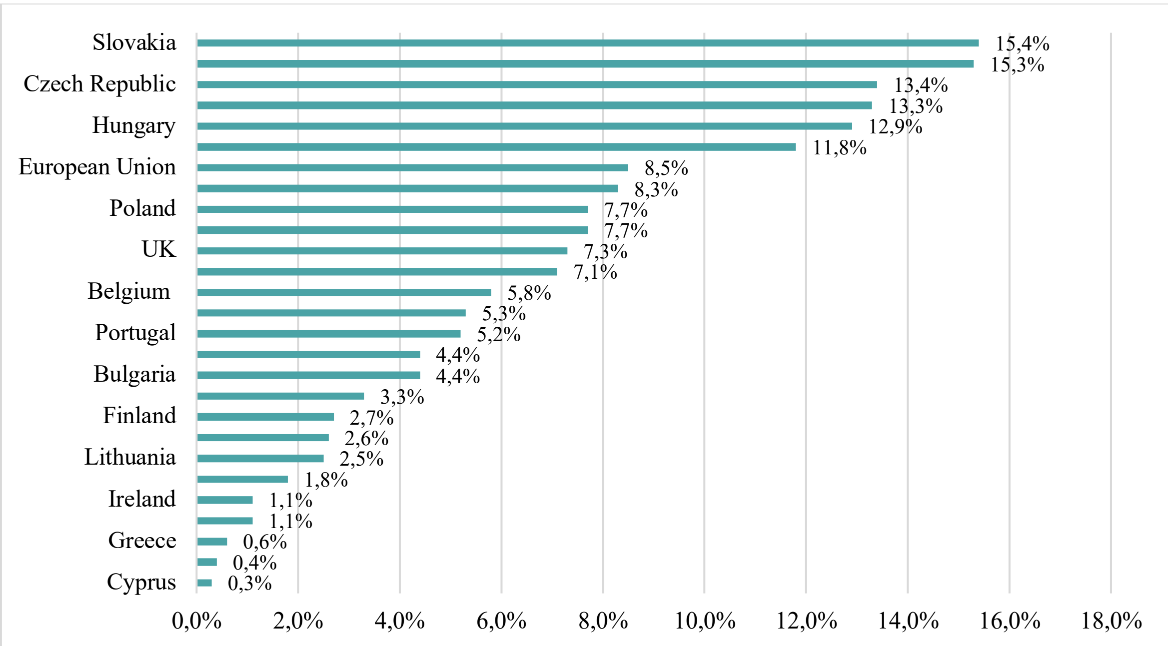
Table 1.5. Direct automotive workers by country in 2017

Austria	33 843	France	223 000	Poland	202 858
Belgium	29 181	Germany	869 118	Portugal	37 071
Bulgaria	24 380	Greece	1 928	Romania	185 242
Croatia	2 861	Hungary	97 688	Slovakia	77 062
Cyprus	85	Ireland	2 359	Slovenia	14 582
Czechia	177 156	Italy	162 876	Spain	157 610
Denmark	1 377	Latvia	2 087	Sweden	79 600
Estonia	2 860	Lithuania	5 376	UK	186 000
Finland	8 655	Netherlands	22 682		
European Union – 2 607 477					

Source: EUROSTAT

However, the different situation is in terms of the share of direct automotive employees in total manufacturing in the country. Slovakia, Romania and the Czech Republic have the highest shares of direct automotive employees that equal to 15.4%, 15.3% and 13.4% respectively. The average share in the European Union is 8.5%. The lowest shares Cyprus, Denmark and Greece have. Germany that has a bigger population and is the leader of automotive manufacturing in terms of the amount of production, also has bigger than average share of workers.

Figure 1.16. Shares of direct automotive employment in total manufacturing in 2017

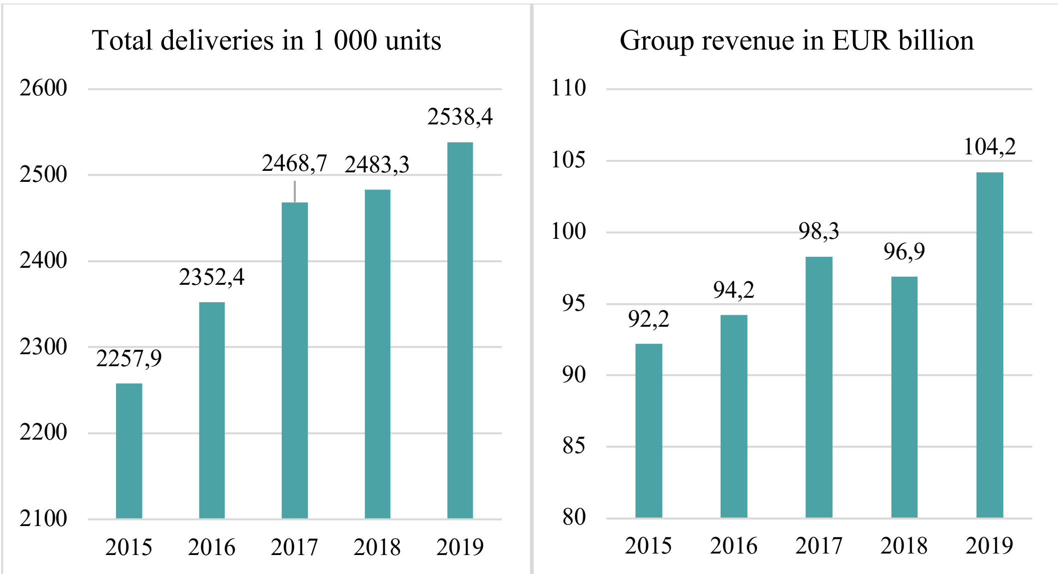


Source: EUROSTAT, 2017

The most popular car producers in Europe that should be described in details to be able to analyse following models are BMW Group, DAIMLER AG, FCA Group, Ford Motor Company, Geely Group, General Motors Europe, Group PSA, Hyundai Motor Group, Mahindra & Mahindra, Renault-Nissan Group, Tata Motors, Toyota Motor Corporation and Volkswagen Group.

1. ***BMW Group*** is the German multinational company that is presented in 15 countries and has more than 50 facilities. The company was established in 1916 as a manufacturer of aircraft engines but today it produces luxury vehicles and motorcycles. Its automobiles are known under the brands like BMW, Mini and Rolls-Royce.

Figure 1.17. Selected financial indicators of BMW Group



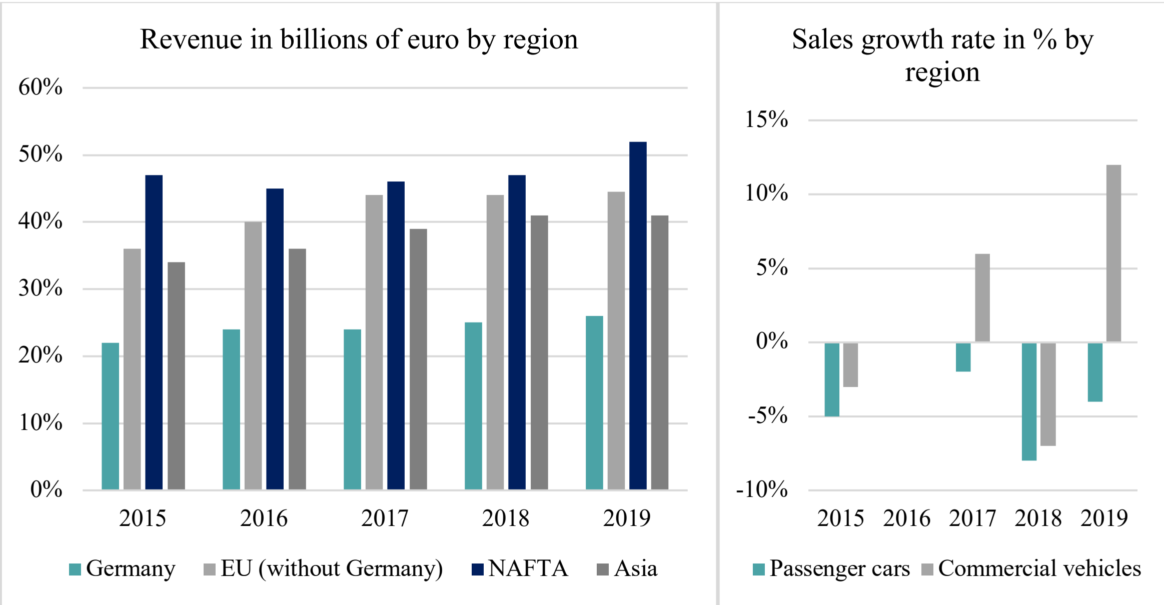
Source: Annual report BMW Group, 2020

The company has a positive tendency in the quantity of produced vehicles and continue to increase its revenue.

2. ***DAIMLER AG*** is another German manufacturer of a variety of vehicles worldwide. The company was established in 1926 in the result of the merge of Benz & Cie and Daimler Motoren Gesellschaft. The company is an owner of such brands: Mercedes-Benz, Mercedes-AMG, Smart Automobile, Detroit Diesel, Freightliner, Western Star, Thomas Built Buses, Setra, BharatBenz, Mitsubishi Fuso, MV Agusta. It also specialises on luxury brands like Mercedes-Maybach that was re-established in 2015 and Rolls Royce Limited where owns 50% of shares. In 2019 the producer sold 3.3 million vehicles therefore is the 13th largest car manufacturer.

DAIMLER AG is known for its alliances and partnerships. One of the latest was in 2010 with Renault-Nissan Group included engine and model sharing.

Figure 1.18. Selected financial indicators of DAIMLER AG



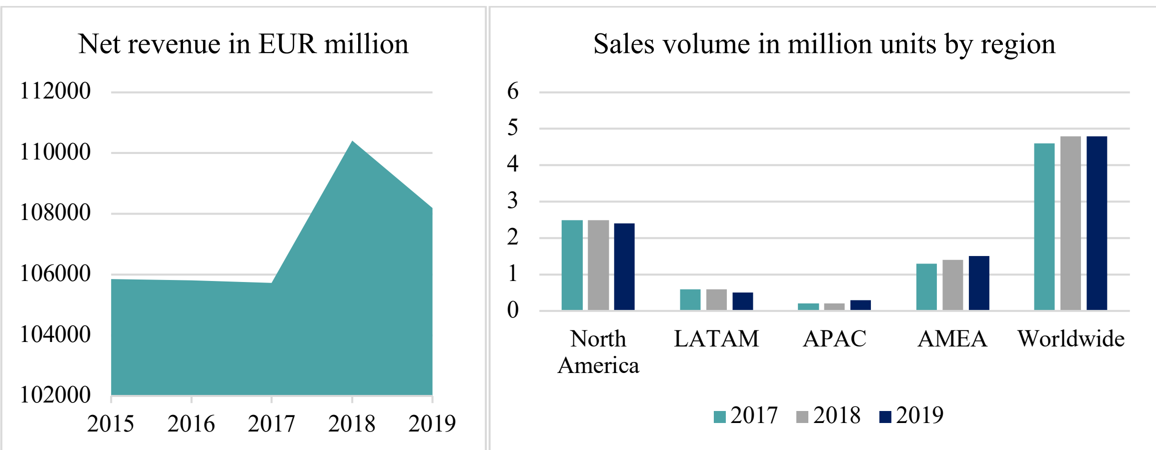
Source: Annual report DAIMLER AG, 2020

The company also has a positive tendency in revenue in every region. In 2019 the highest growth in revenue was in the NAFTA region, sales of passenger cars decreased by 5% worldwide.

3. ***FCA Group*** is an American-Italian group that is the 8th biggest car producer in the world. The group was established in 2014 as a result of the merge of Italian Fiat and American Chrysler. The most popular brands that the company owns are Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia, Maserati, and Ram Trucks. Till 2016 Ferrari was a part of Fiat Chrysler Automobiles.

During last years, there is a lot of discussion about merging with French Groupe PSA on a 50-50 all stock basis.

Figure 1.19. Selected financial indicators of FCA Group

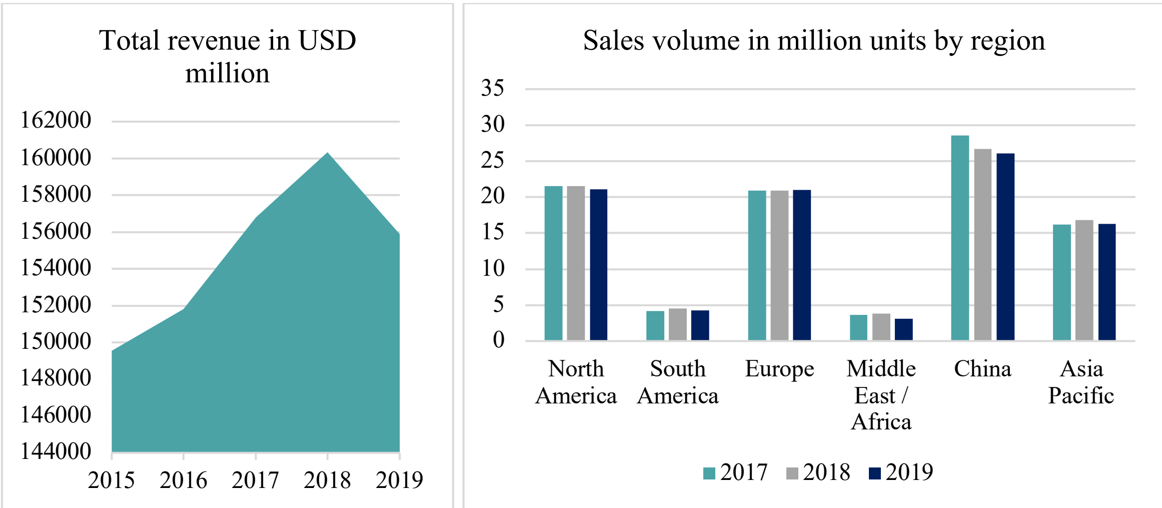


Source: Annual report FCA Group, 2020

FCA Group has decreased the total amount of sales in 2019 in comparison with two previous years. Also, net revenues have decreased by a small amount in 2019, however, the company demonstrates the positive tendency starting from 2015.

4. ***Ford Motor Company*** is an American multinational company that was established in 1903 by Henry Ford. It sales under two brands: Ford and Lincoln for luxury vehicles. Ford's subsidiaries Jaguar and Land Rover were sold to Tata Motors in 2008, while from 1999 to 2010 the company-owned Swedish Volvo. Moreover, Ford Motor Company is the second-largest producer in the United States and the 5th biggest in the world.

Figure 1.20. Selected financial indicators of Ford Motor Company



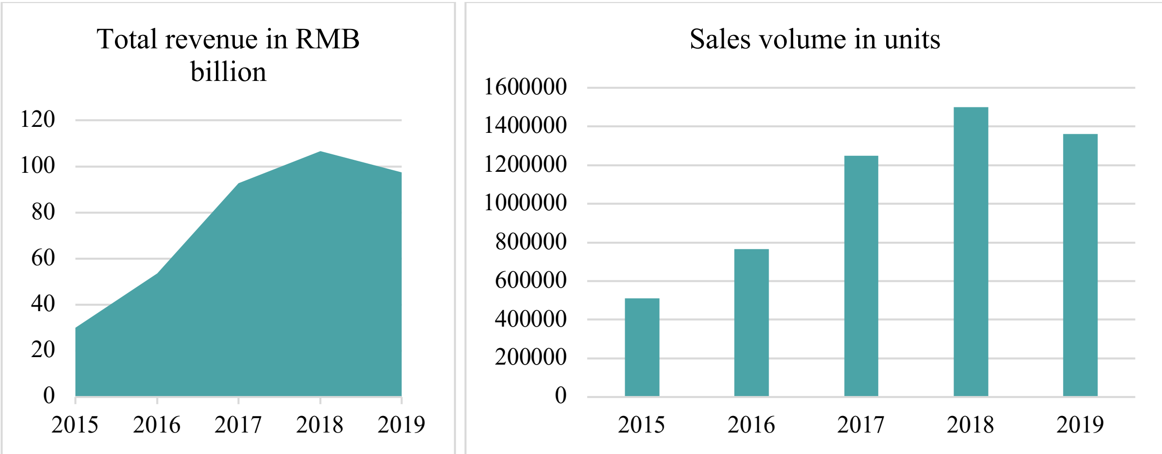
Source: Annual report Ford Motor Company, 2020

Ford Motor Company has decreased the level of sales during the last three years that also had an impact on net income. However, the total revenues haven't changed significantly.

5. ***Geely Group*** is a Chinese multinational corporation that was established in 1986 and entered the automotive industry in 10 years after it. The company sells passenger vehicles under these brands: Geely Auto, Lotus, Lynk & Co, PROTON, and Volvo while London EV Company and Yuan Cheng Auto are main brands for commercial vehicles.

Before the acquisition of Volvo and some British sport car companies and taxi producer, Geely Group has produced its own cars.

Figure 1.21. Selected financial indicators of Geely Group



** Inclidung the sales volume of "Kynk&Co" vehicles from 2017*

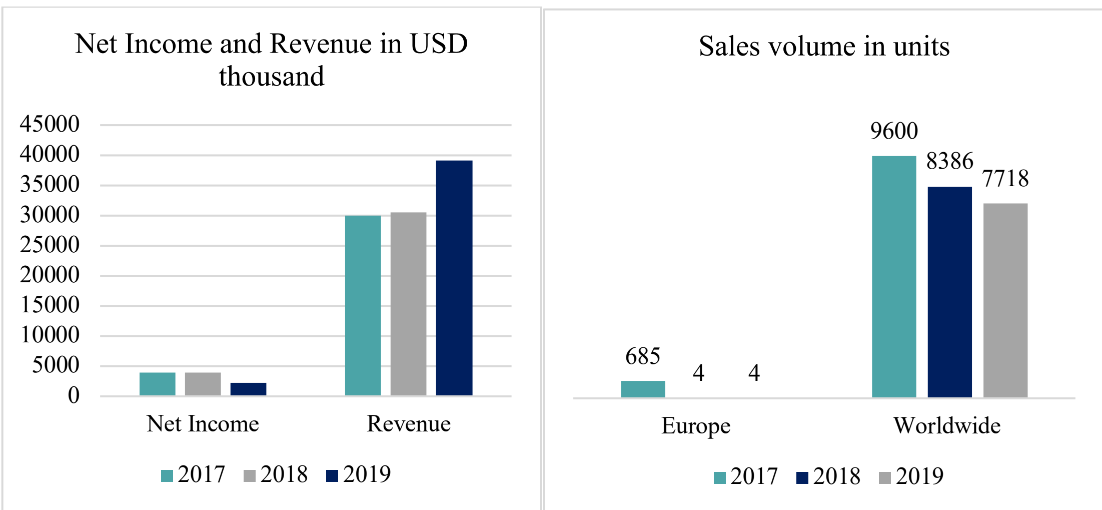
Source: Annual report Geely Group, 2020

The revenue demonstrates a positive tendency with small decreasing in 2019 that can be connected with a lower level of sales during the year.

6. ***General Motors Europe*** is a subsidiary of the American multinational company established in Detroit in 1908 that is the biggest vehicle producer in the United States. Despite the financial problems in the past, in 2019 the company was ranked 13th as the biggest company in the United States by total revenue. Moreover, it is presented in 15 countries and includes such brands: Chevrolet, Buick, GMC and Cadillac.

General Motors Europe as a subsidiary was established in 1986 and operates 14 facilities in 9 countries. The main brands of the company were Vauxhall and Opel however in 2017 General Motors (GM) agreed to sell these brands to French Group PSA.

Figure 1.22. Selected financial indicators of General Motors



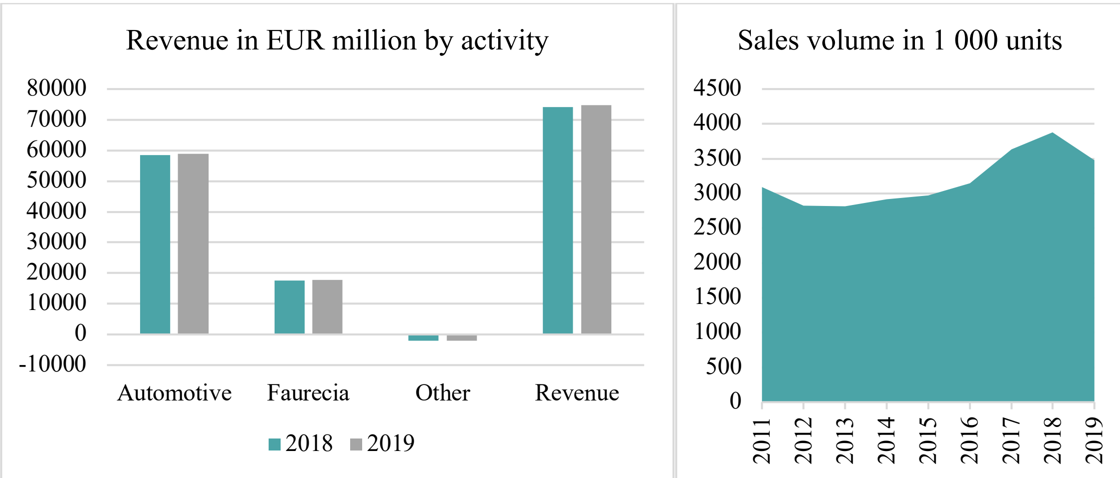
Source: Annual report General Motors, 2020

General Motors demonstrates a positive tendency of revenue and is one of the more stable companies for now. The net income is decreasing during the investigated period. Also, a European subsidiary sells own brands on the European market therefore the market share is almost zero.

7. ***Group PSA*** is a French international corporation that was founded in 1976. The main business activities are in the automotive industry where the company realises cars and motorcycles. The main brands owned by the group are Peugeot, Citroën and DS. From 2016 the company started the expansion and acquisition activities and as a result bought Opel and Vauxhall as was mentioned before. Moreover, the company agreed to merge with Fiat Chrysler Automobiles as was described above.

Peugeot is the biggest and the most popular brand of the company and rank as one of the best-seller vehicles on the European market. Therefore, group PSA is the 3rd biggest Europe-based automotive producer.

Figure 1.23. Selected financial indicators of Group PSA

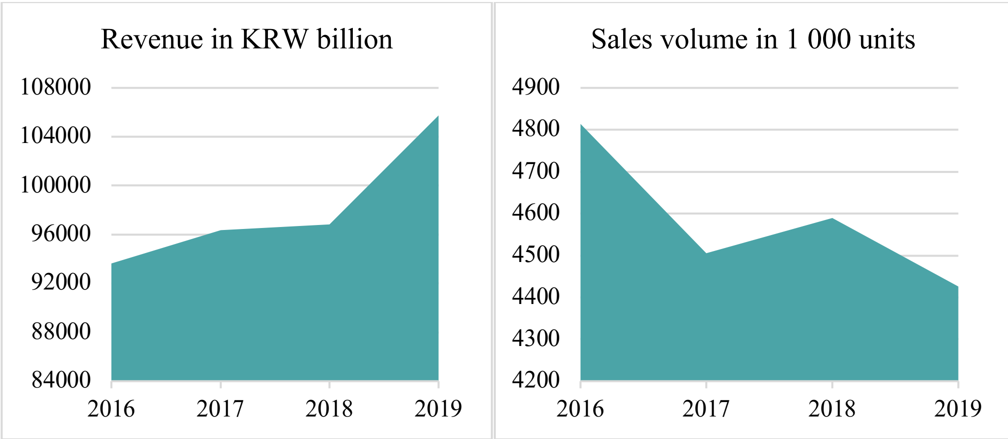


Source: Annual report Group PSA, 2020

The group shows a stable tendency in terms of revenue and other financial indicators. Moreover, the positive trend is presented in a total number of vehicles sold by the group with decreasing during the last year.

8. ***Hyundai Motor Group*** is a South Korean international company that was established in 1998 as a result of the purchase of 51% of KIA Motors. In 2017 the company was the 3rd largest automotive manufacturer in the world after Japanese Toyota and German Volkswagen Group. The company is a part of the second-largest conglomerate in South Korea after Samsung and has a variety of other business activities. It also has own luxury brand - Genesis Motor.

Figure 1.24. Selected financial indicators of Hyundai Motor Group



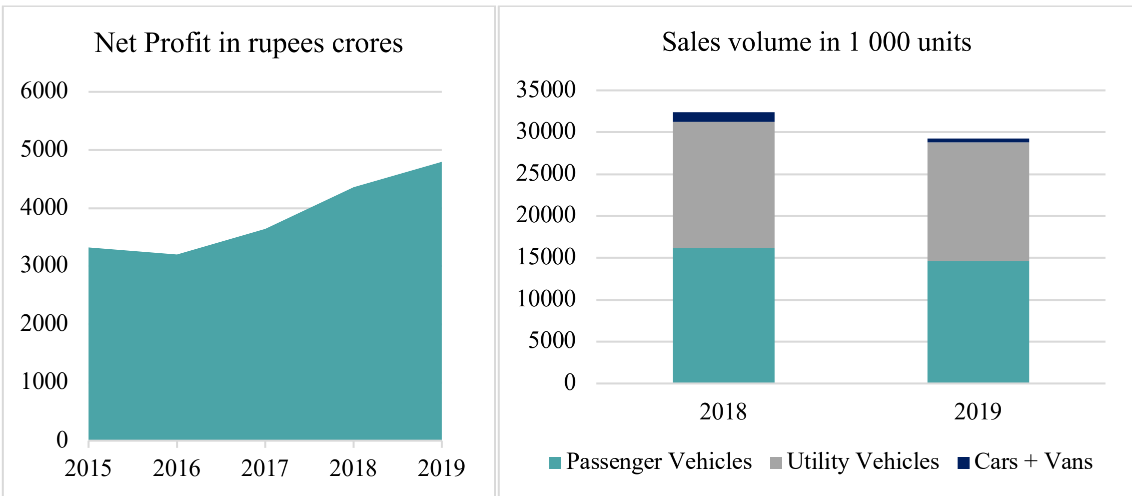
Source: Annual report Hyundai Motor Group, 2020

Despite the decreasing of the total amount of sales over the investigated period, the company has a positive tendency in sales revenue.

9. ***Mahindra & Mahindra*** is an Indian multinational company that was established in 1945. In 2018 the company was ranked as 17th the biggest in India. It focuses on SUVs, sedans and pickups. Additionally, the company is known as one of the biggest producers of tractors.

The company's presence in Europe is presented by based in Italy Mahindra Europe.

Figure 1.25. Selected financial indicators of Mahindra & Mahindra



Source: Annual report Mahindra & Mahindra, 2020

The total quantity of sold vehicles decreased in the last year however it didn't influence reported net profit that demonstrated a low level of sensitivity to changes in automotive sales. This can be explained by other numerous business activities performed by the company worldwide.

10. ***Renault-Nissan Group*** is the strategic alliance between two companies that was established in 1999. In 2017 Mitsubishi has joined the group and changed its name to Renault–Nissan–Mitsubishi Alliance. This alliance allowed to sell more than 1 in 9 vehicles worldwide and made them a leading light vehicle manufacturing group in the world. Moreover, in 2018 the alliance as ranked as the leader in plug-in electric vehicles.

The group that is not an acquisition or a merge in the traditional way, has 10 brands under the control of the group are Renault, Nissan, Mitsubishi, Infiniti, Renault Samsung, Dacia, Alpine, Datsun, Venucia and Lada.

Table 1.6. Global Sales by the Alliance

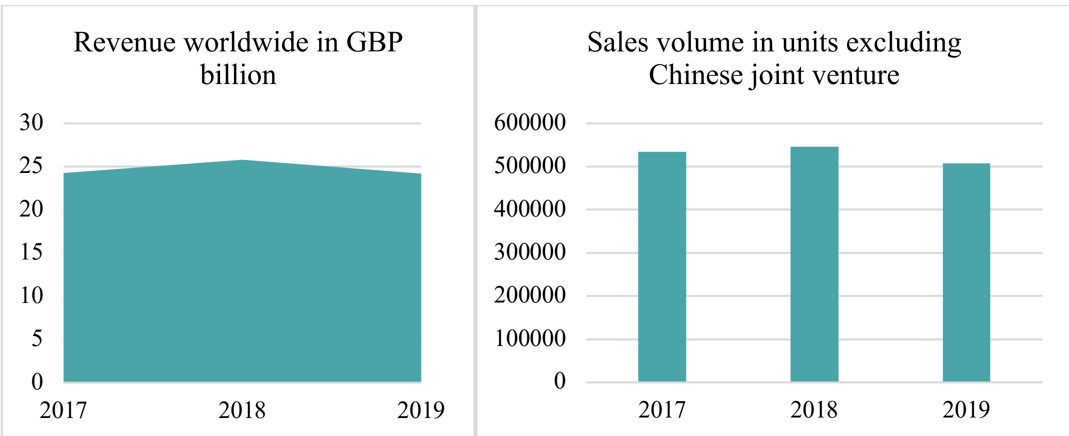
Year	2013	2014	2015	2016	2017	2018
Renault	2 628 208	2 712 432	2 801 592	3 182 625	3 761 634	3 884 295
Nissan	5 102 979	5 310 064	5 421 804	5 559 902	5 816 278	5 653 683
Mitsubishi				934 013	1 030 454	1 218 897
AvtoVAZ	533 634	448 114	305 491	284 807		
Total	**8 264 821**	**8 470 610**	**8 528 887**	**9 961 347**	**10 608 366**	**10 756 875**

Source: Annual report Renault-Nissan Group, 2019

The results from the investigated period demonstrate the increase of the total amount of sales by the group of companies.

11. ***Tata Motors*** is an Indian international corporation that is a part of Tata Group conglomerate and was established in 1945 as a locomotive manufacturer. In Europe, auto manufacturing and assembly plant are located only in the United Kingdom. The main brands under the control of the company are Jaguar Land Rover and South Korean Tata Daewoo. Additionally, the company has a joint venture with Fiat Chrysler and produces some vehicles in strong cooperation. While in 2017 the company signed the memorandum with Volkswagen to develop the automotive industry in India.

Figure 1.26. Selected financial indicators of Tata Motors



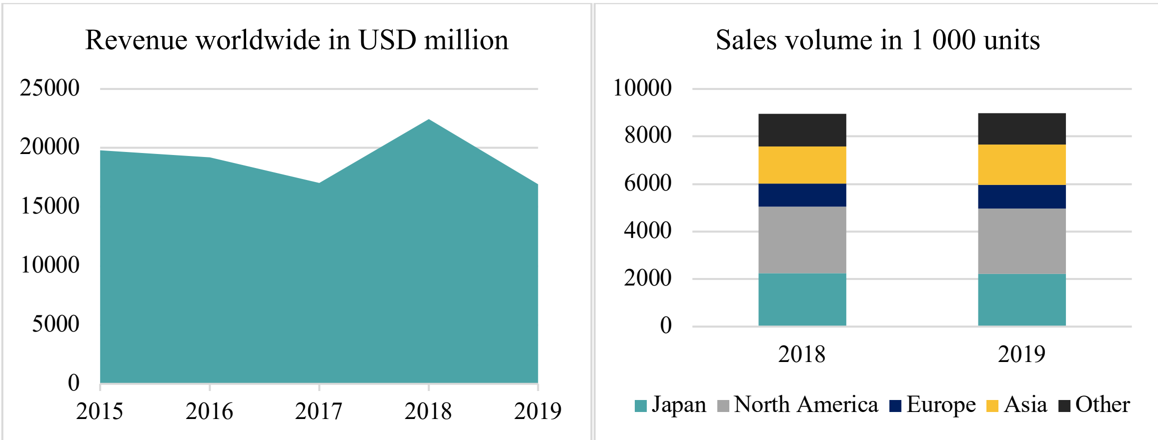
Source: Annual report Tata Motors, 2020

Tata Motors doesn't demonstrate any significant growth in terms of revenue and profit. Moreover, it is possible to notice that profit has a tendency to decrease along with the total number of sales excluding China joint venture.

12. ***Toyota Motor Corporation*** is a Japanese international company that was founded in 1937 and currently is the 10th biggest company in the world by revenue. Following German Volkswagen, the company is the second-biggest automotive producer in the world by sales. Moreover, Toyota Motor is the biggest company in terms of hybrid car sales and is one of the largest companies that implement hybrid solutions into the mass market.

The main 5 brands under the corporation control are Toyota, Hino, Lexus, Ranz, and Daihatsu. Additionally, it holds some stakes in Subaru, Isuzu, Mazda and Suzuki.

Figure 1.27. Selected financial indicators of Toyota Motor Corporation

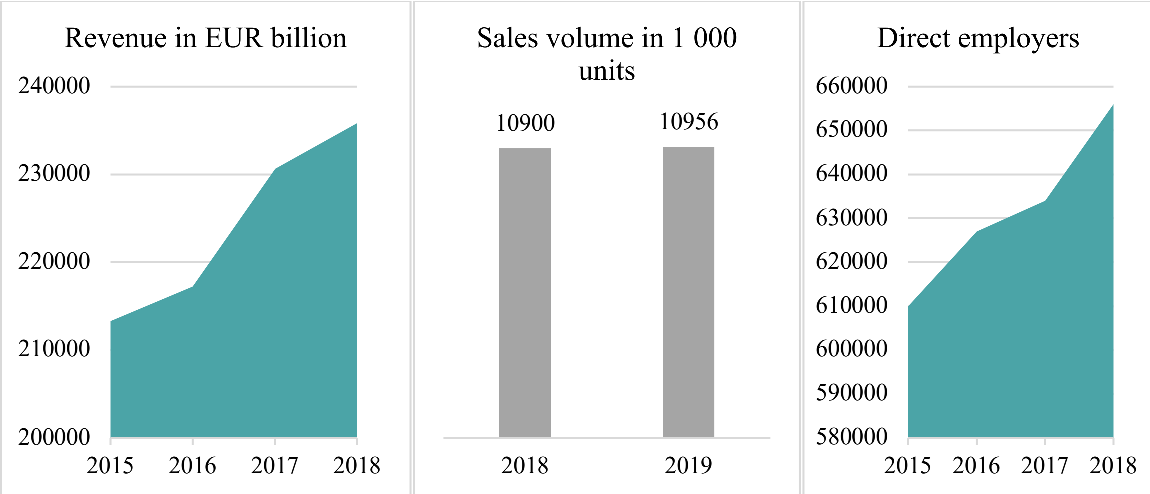


Source: Annual report Tata Motors, 2020

Total sales increased by 13 thousands of vehicles in 2019, however, annual net income decreased.

13. ***Volkswagen Group*** is the German multinational corporation that was established in 1937 and is the biggest automotive producer in the world. The group has the largest market share in Europe during the last two decades when the biggest market share is in China that is equal to 40%. The main brands for passenger vehicles are Audi, Bentley, Bugatti, Lamborghini, Porsche, SEAT, Škoda and Volkswagen. Moreover, the group owns the leading European commercial vehicles like MAN and Scania.

Figure 1.28. Selected financial indicators of Volkswagen Group



Source: Annual report Volkswagen Group, 2020

During the last five years, the company has a positive tendency to grow in every financial indicator.

To sum up, this section describes the current organisations that analyse actual development and challenges on the market along with academic researches that use modelling and advanced techniques to define the influence of macroeconomic indicators on the automotive industry in Europe and worldwide. Additionally, the analysis of the current situation on the market presented with all possible tendencies and challenges. The European automotive industry as one of the main sectors in many countries' economy has its own specificities that influence all automotive players on the market. Moreover, some tendencies confirm the necessity to be innovative, well developed, flexible and prepared for future changes. Also, the differences between different regions are described with all possible factors that have an impact on the final consumer. Finally, all main European automotive sellers are analysed to be able to interpret all results from further modelling and clusterisation.

2. Methodology

The following section describes all methodology is going to be used in the modelling and the analysis. The panel data model along with cluster analysis are going to be used in *RStudio, Matlab* and *Gretl*. That is why all theoretical principles of these types of models are described and represented in formulas. Moreover, the main basic assumption of the described model is presented in details because every constructed model can be used for further analysis and interpretation only in complying with all the main criteria and standards.

2.1. Panel data model with fixed effects

Empirical research in economics usually based on time series. In the case of macroeconomic indicators influence on sales in different European countries and on particular producers, it is necessary to use a panel data model.

Moreover, panel data represent observations of a certain number of objects in one set over particular periods of time. Actually, it is a combination of cross-section and time-series types of data. This allows analysing more complex processes in comparison to models based on time series or cross-sectional data only.

The general equation of the panel data model (Baltagi, 2008):

$$Y_{it} = a + X'_{it}\beta_{it} + \varepsilon_{it} \tag{1.1}$$

where Y_{it} – the value of particular object *i* in *t* time, where *i = 1,2,3,…,N* – the amount of objects, *t = 1,2,3,…,T;* – the amount of periods;

X'_{it} = $\{X_{1it}, X_{2it}, \dots, X_{1it}\}$ – a vector of explanatory factor' s order;

a – scalar;

β_{it} - a vector of model parameters that measure the partial effects of a X_{it} change in the period *t* for certain *i*;

ε_{it} – the perturbation of the object *i* in *t* time.

In view of the constancy of the parameters β_{it} for all values of *t* and *i* that is a standard assumption for practical application, the general equation looks like:

$$Y_{it} = a + \beta_1 X_{1it} + \beta_2 X_{2it} + \dots + \beta_k X_{kit} + \varepsilon_{it} \tag{1.2}$$

where Y_{it} – the value of particular object *i* in *t* time, where *i = 1,2,3,…,N* – the amount of objects, *t = 1,2,3,…,T;* – the amount of periods;

a, β_j - unknown parameters of the model, where *j = 1,2,3,…,k*;

X_{jit} – the value of j-factor for the particular object *i* in *t* time;

i = 1,2,3,…,N;

t = 1,2,3,…,T.

Panel data models can be divided into ones that have a unidimensional error component and those that have a two-dimensional error component. In the first type, the value of a random variable is divided into unobservable specific individual effects and residual noise, while the second one has additional unobserved time effects. The main difference is in the possibility to consider the time effects that may be relevant and necessity during the analysis (Mátyás and Sevestre, 2008):

$$\varepsilon_{it} = \mu_i + \eta_t + u_{it} \quad (1.3)$$

where μ_i indicates unobserved specific individual effects; η_t - unobservable time effects and u_{it} - residual noise.

In addition, models can be built with fixed or random effects. In general, fixed effects help adequately evaluate the data in terms of creating the conditions when the sum of all residues is zero. This is achieved by dividing the elements by a particular classifier into groups that allow calculating individual regression lines with corresponding cross-sections.

Moreover, it is important to pay attention to statistical differences in values of intercepts in fixed-effects models. There is a specific test for the purpose where the null hypothesis assumes all these intercepts are equal to zero. If the null hypothesis has not been discarded, the use of the panel data the model with the single intercept has the advantage. Another important test is the Hausman test to check correlations between individual effects and explanatory variables. It also helps to choose which model to use: with fixed or random effects. The null hypothesis of the test is the assumption of no correlation. Therefore, the result of the test indicates that in case of the presence of correlation it is worth to use a fixed-effects model, while in case of its absence - with random or fixed effects.

There is a more theoretical approach commonly used in the practice to choose the right specification for the model. In case the dataset represents total market data it is better to use a panel data model with fixed effects, otherwise random effects can be more accurate.

Typically, the ordinary least squares (OLS) method is used to construct panel data with any type of effects. The main advantage is in easy calculations and statistically adequate estimations. It is one of the regression analysis methods to estimate unknown values from the results of measurements containing random errors. The main idea is to minimize the sum of squares of real values' deviations (Goldberger, 1964):

$$\sum_{i=1}^{N} e_i^2 = \sum_{i=1}^{N} \left(Y_{it} - \hat{Y}_{it}\right)^2 \to min \quad (1.4)$$

where $\hat{Y}_{it}$ - a regression-estimated target value of *i*-object in *t*-time.

The next important part it is worth to mention is a type of chosen data. Obviously, to procced the described model panel data is needed. This type of data consists of two other types (time-series data and cross-sectional) therefore describes variables collected over some time and for some number of variables (Gujarati, 2003).

Additionally, there is a possibility of biased results in response to outliers that have a strong impact. The dataset has to analysed in the response of possible outliers that lie in the abnormal distance and can be simple mistakes or unnecessary observations that don't follow the main pattern of the model. There are two main ways how to detect them: using the mean with standard deviation (3 standard deviations from the mean) and the median with interquartile range (IGR) (upper / smaller quartile plus / minus 1,5*IQR respectively). The main solutions in case of such a problem are trimming and winsorizing that allow to settle outliers to a certain value in the chosen range.

The next question is in the influence of independent factors on the dependent one. First of all, it can be checked by the correlation coefficient that calculates a linear relationship between selected variables and takes values from -1 to +1.

$$r_{YX} = \frac{\frac{1}{N}\sum_{i=1}^{n}(X_i-\bar{X})(Y-\bar{Y})}{\sqrt{\frac{1}{N}\sum_{i=1}^{n}(X_i-\bar{X})^2\frac{1}{N}\sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \quad (1.5)$$

A coefficient higher 0 indicates a positive relationship between metrics and lees than 0 - negative respectively. The common theory indicates that the value between 0 and 0.3 demonstrates a weak connection between variables, from 0.3 to 0.7 - medium, and higher than 0.7 - strong correlation between selected ratios. Accordingly, the same logic is for coefficients of less than 0.

The next important element is the level of determination that also measures the density of a connection between two or more metrics and checks the overall adequacy of the model. It demonstrates the degree of explanation of the dependent variable' changes by changing of independent variables:

$$R^2 = \frac{\sum_{i=1}^{N}(\hat{Y}_i-\bar{Y})^2}{\sum_{i=1}^{N}(Y_i-\bar{Y})^2} \quad (1.6)$$

The coefficient of determination always has a positive sign and takes a value from 0 to 1. The closer it gets to 1, the better the model is because of the higher level of explanation of the dependent variable by changings in independent metrics.

Another important factor to determine the impact of each variable on independent one is the Student's t-test, which checks for significance the differences between the sample mean and the mean of the total sample. The t-static for every single factor is possible to compare with t-critical in according to the chosen level of significance and the degree of freedom. This allows to determine whether the factor is significant and influences the dependent variable. Moreover, in case t-static is less than critical the coefficient is close to zero and is not significant. Finally, it is worth to use Fisher's criterium (F-stat) with the null hypothesis of the insignificance of all coefficients that simultaneously are equal to zero.

Overall, panel data models have some significant advantages over other approaches to analyse. First of all, the longitudinal data models are comprehensive character and allow to analyse data at the individual level using the benefits of time series and cross-sectional types of data. The next advantage is a significant increase in the total amount of observations that reduces the possibility of multicollinearity and increases the degrees of freedom. Finally, panel data models also make helps to avoid specification errors caused by the absence of some significant variables.

2.2. The basic assumption of the described model

In addition to all these tests, the adequacy of the model depends on the holding of all base assumption. To achieve one of the best-unbiased models, the main 5 assumptions have to be tested (Gujarati, 2003):

1. The average value of the errors is zero

This assumption is automatically held because of the constant term that is included in the model. Otherwise, the OLS estimation can be biased and R-square can be negative

2. The variance of the errors is finite and constant

The assumption of homoskedasticity often is violated because of the correlation between the variance of errors with one of the explanatory or even dependent variable. As a result, the model can't be determined as the best one despite unbiased OLS estimator. Also, t-statistics can be violated that makes impossible to analyse parameters' significance. To solve the problem, the individual variables should be transformed (the variance stabilising transformations or dividing the final equation by the independent variable that causes heteroscedasticity problem). Moreover, it is possible to use alternative estimators or use White's heteroscedasticity-consistent standard errors estimator for the dataset over 50 observations).

3. The covariance between the error terms is zero

There are two general methods to determine the problem: graphical method using a plot of residuals over time, against previous ones and a variety of statistical tests. The most popular are the Darbin-Watson test and the Breusch-Godfrey test for higher orders of autocorrelation.

$$d = \frac{\sum_{i=2}^{N}(e_i - e_{i-1})^2}{\sum_{i=1}^{N} e_i^2} \tag{1.7}$$

where e_i – residuals in the model.

Based on the number of factors and the number of observations, the calculated critical values are plot on the interval from 0 to 4. As a result, the modelled value can be in the area of positive autocorrelation, uncertainty or no autocorrelation. The closest the value is to 2, the higher chances to receive the model without autocorrelation problem.

The test is simple in use but has some limits and is not valid for the model without *const* term, in case the dependent variable is lagged and test the autocorrelation of the first period. The violation of this assumption causes the misleading conclusion about the statistical significance of the parameters but doesn't disrupt OLS estimation in a strong way.

To avoid this problem it is possible to change some variables, modify lags or select another functional form of the equation.

4. The explanatory variables are not correlated with the errors

The violation of the assumption can cause biased parameters' estimators and is important from the technical and interpretation point. There are three main situations when it can be disrupted: reverse causation, measurement errors or omitted explanatory variable. To avoid such a problem, it is necessary to include all relevant explanatory variables and analyse their correlations with the dependent variable and independent that is going to be replaced.

5. The random errors are normally distributed

The null hypothesis demonstrates the normal distribution of residues. The testing of the random value for normality is based on that according to the normal distribution, the asymmetry and kurtosis coefficients are equal to zero. Therefore, deviations indicate the violation of the normal distribution:

$$JB = \frac{N}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right) \tag{2.8}$$

where *n* is a number of observations, *S* – skewness and *K* indicates kurtosis.

$$S = \frac{\hat{\mu}_3}{\hat{\sigma}^3} = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i-\bar{x})^3}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_i-\bar{x})^2\right)^{3/2}} \tag{2.9}$$

$$K = \frac{\hat{\mu}_4}{\hat{\sigma}^4} = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i-\bar{x})^3}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_i-\bar{x})^2\right)^{2}} \tag{2.10}$$

where $\hat{\mu}_3$ and $\hat{\mu}_4$ are the estimates of 3^d and 4^{th} central moments.

The calculated coefficient compares with a table that indicates violation or following of the assumption. The violation of the hypothesis makes impossible to determine the right coefficient of Student and Fisher criteriums that disrupt the general level of adequacy of the model. To solve such a problem, it is necessary to expand the sample.

2.3. Cluster analysis and SOM as methods of a data bundling

For further analysis, the data should be organised into visual groups that can be achieved by the cluster analysis. The main idea is to find the number of groups or clusters and to determine the objects into particular ones. The obtained data are analysed according to certain signs and are divided into clusters so that the members of one cluster own similar indicators and coefficients and differ from other groups. Also, this method is convenient because it can be used even when the normality of random distribution is not fulfilled and when there is an only small dataset for the analysis (Gujarati, 2003)..

The first point to consider is how to measure similarities or differences between chosen variables. As a result, all data are going to be used in the research must be standardised that allow to compare and divide:

$$X^* = \frac{X - \bar{X}}{\sigma} \tag{2.11}$$

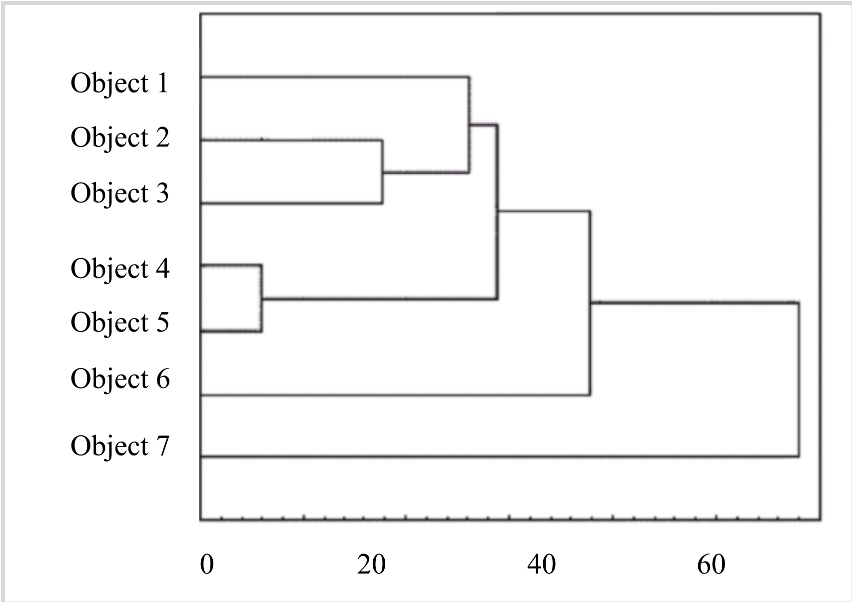
where *X* is a particular value from the dataset (variable over time); $\bar{X}$ – mean of the variable over time; σ – standard deviation.

It should be noted that cluster analysis can be performed by different clustering methods. In general, they can be divided into two groups: hierarchical and non-hierarchical. However, each of these groups has a variety of approaches and algorithms to analyse.

The hierarchical clustering has the advantage of avoiding the problem of how many clusters it is better to choose for the analysis. The main idea of such a method is to merge objects into clusters or split large ones into smaller groups. These approaches are called agglomerative and divisive accordingly.

An example of an agglomerative hierarchical clustering approach is a tree diagram that presents objects on the left side that is currently unique. The idea is to gradually reduce the uniqueness of these objects by combining them into groups. As a result, all these objects are connected to one cluster at the end. Moreover, hierarchical trees are used not only in cluster analysis but also in other methods of data analysis. There are also various ways to construct dendrograms: objects can be arranged vertically and horizontally. However, the main value of a dendrogram is its ability to determine the number of possible clusters and their composition of analysed objects (Figure 2.1).

Figure 2.1. An example of the clustering tree



In the presented dendrogram, the horizontal axis indicates the distance of the corresponding objects to merge. There is a variety of possible distance measures commonly used in practice. The Euclidean distance is the most popular according to academic studies and presents the geometric distance in multidimensional space.

$$dist = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \tag{2.12}$$

where x_i – the value of *i*-characteristic of *x*-object; y_i – the value of *i*-characteristic of *y*-object.

It is important to note that the Euclidean distance is calculated by input, not standardized data. When it is necessary to give more weight to more distant objects, it is better to use the square of the Euclidean distance.

$$dist = \sum_{i=1}^{n}(x_i - y_i)^2 \tag{2.13}$$

If for each *i* it is required to give a certain "weight" *w* according to the level of importance, it is possible to use a weighted Euclidean distance.

$$dist = \sqrt{\sum_{i=1}^{n} w_i(x_i - y_i)^2} \tag{2.14}$$

To decrease the influence of some outliers that couldn’t be omitted in the analysis, it is possible to use another formula without squares:

$$dist = \sum_{i=1}^{n}|x_i - y_i| \tag{2.15}$$

To change the importance assigned to the dimensions for which the objects are different the next formula can be used:

$$dist = \left(\sum_{i=1}^{n}(x_i - y_i)^p\right)^{\frac{1}{r}} \tag{2.16}$$

Finally, in case the distance between two vectors is bigger than their differences along any coordinate dimension, it is better to use Chebyshev distance.

$$dist = \max|x_i - y_i| \tag{2.16}$$

To determine the distance between sets of observations there are other linkage criteria:

- maximum or complete-linkage clustering;
- minimum or single-linkage clustering;
- unweighted average linkage clustering where cluster distance is defined as the average distance between all pairs of objects;
- Weighted average linkage clustering (WPGMA) where the distance between clusters of different sizes is determined by the weighted average distance between all pairs of objects. This method is similar to the previous one but eliminates the problem of cluster size's inequality.
- centroid linkage clustering (UPGMC);
- minimum energy clustering;
- the sum of all intra-cluster variance;
- the increase in variance for the cluster being merged, where the distance is determined using analysis of variance. Accordingly, the new cluster combines those clusters that merge with the smallest increment in the total distance. This method commonly used in practise, although it tends to create small clusters;
- the probability that candidate clusters spawn from the same distribution function;
- the product of in-degree and out-degree on a k-nearest-neighbour graph;
- the increment of some cluster descriptor.

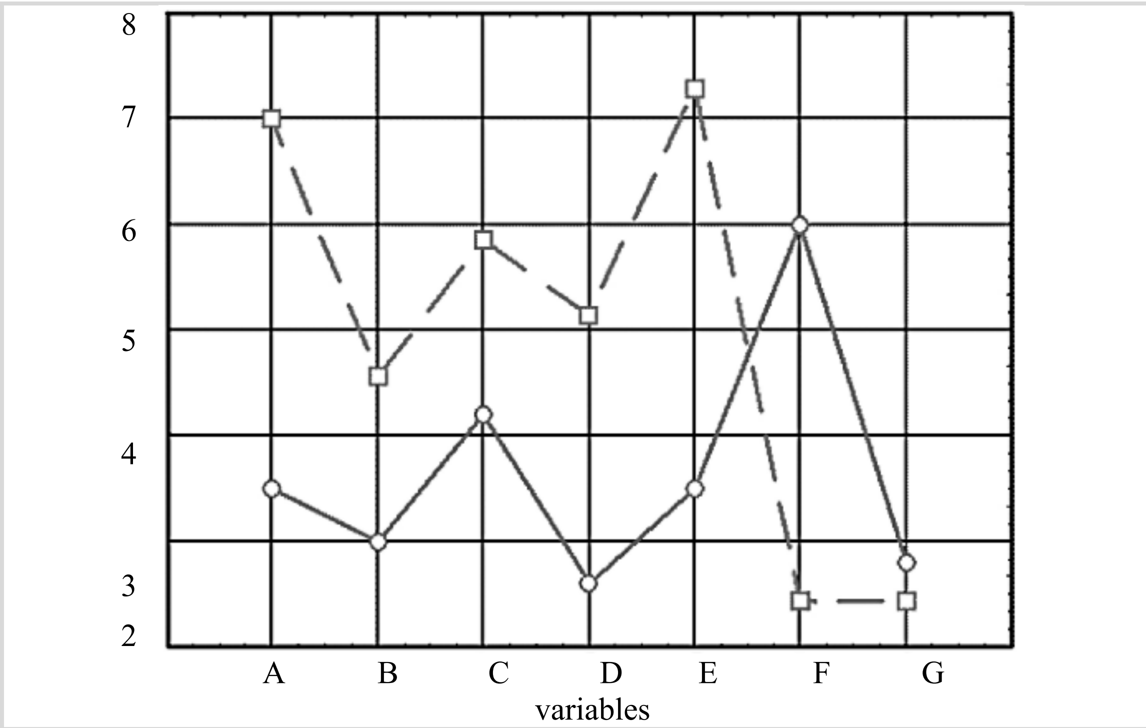
Another popular method of cluster analysis is used K-means method when the estimated number of clusters is determined by the analyst at the beginning. As a result, the investigated objects are divided into the specific quantity of clusters. Moreover, there is a possibility to analyse all divided objects in more details. For example, the analysis of means of each cluster of every investigated variable can be useful to indicate the best performing cluster to compare with others and analyse possible patterns and trends of the objects.

$$V = \sum_{i=1}^{k} \sum_{x_j \in S_i} (x_j - \mu_i)^2 \tag{2.17}$$

where k – the quantity of clusters, S_i – received clusters and $\mu_i$is the mean of points in S_i.

In addition, the K-means method allows to see the coordinates of the cluster centres to all differences in influences of the selected variables (Figure 2.2).

Figure 2.2. The graph of means of two clusters by selected variables

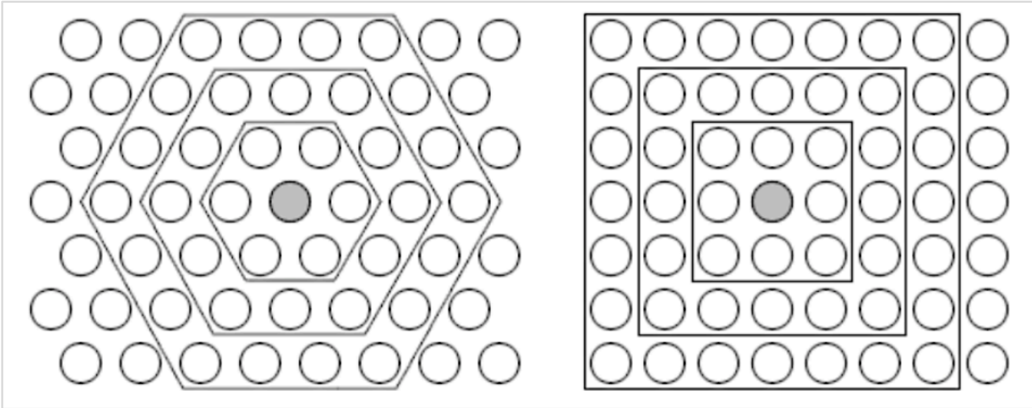


Each line on the graph corresponds to one of the clusters. The selected variables are on the horizontal axis and the vertical axis demonstrates the mean of each cluster based in response to every variable. However, this method is quite sensitive to the choice of the initial centres of the clusters and to outliers that greatly change the mean values. This method can be also inconvenient when it is difficult to specify the number of clusters at the beginning of the analysis.

An additional method of clustering large data sets is the self-organizing map (SOM) algorithm, which also uses the K-means method. The main idea is to organize the neurons into some structure using winning neurons that have the highest number of wins.

In the beginning, it is important to set the number of clusters through which the neural network is formed. Each of the neurons is described by two vectors: a weight vector that has the same dimension as the input data and a vector of the coordinates of the neuron. The standard map is represented in a rectangular or hexagonal shape (Figure 2.3.). However, in practice, analysts often use the hexagonal shape because of the same distances between the centres of neighbour cells that increases the accuracy of the visualization.

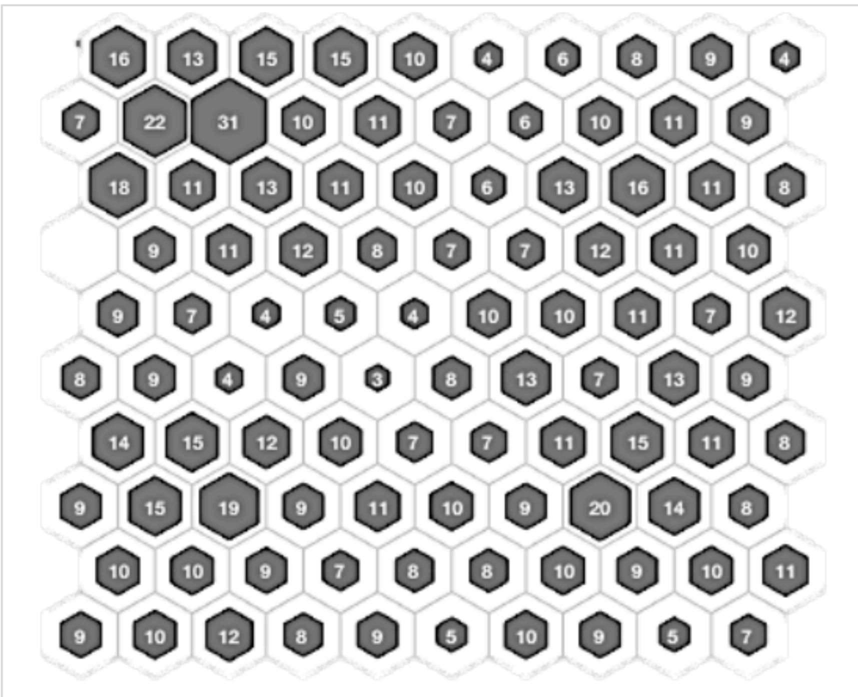
Figure 2.3. Rectangular and hexagonal shape of the SOM topology



During the training, the weights of neurons approach to the input's values. For each observation, the neuron that is most similar in terms of weight is selected based on the Euclidean distance. Also, the vectors of the weights of several nearby neurons approach to the previous ones. These processes end until the achievement of the specific level of the error that was specified at the beginning. As a result, the map classifies the input data into clusters and visually displays it.

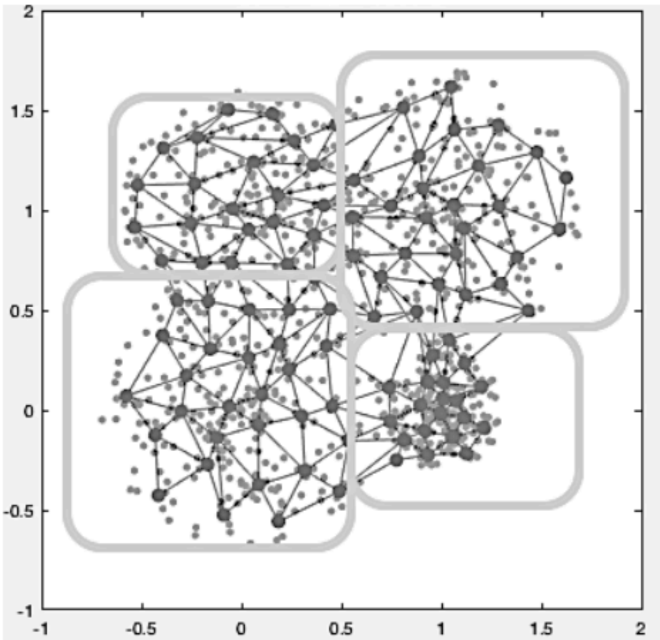
For example, 100 neurons are used for the analysis to demonstrates the number of wins for each object during 200 epochs (Figure 2.4).

Figure 2.4. Hits in the selected SOM topology



Moreover, it is possible to use a grid with weights on axis to represent investigated neurons. Based on these positions, it is easier to see the number of clusters they are merged into (Figure 2.5).

Figure 2.5. Positions of neurons based on their weights



To sum up, this section consists of the description of panel data models with all possible assumptions that are going to be used in the next section during modelling. Moreover, the main theory about cluster analysis is presented here as well. As a result, the data analysis based on cluster techniques can be implemented by various methods and criteria. Therefore, the main types were chosen for further analysis: hierarchical dendrograms and K-means method. In addition, it was proved that K-means method allows to proceed an adequate classification of objects, understand all main processes, trends and to see patterns of the best-performing cluster to make some recommendations based on it.

3. Models and Analysis

The analysis consists of two sides: automotive producers and consumers reaction to changes in the main macroeconomic indicators. A main goal of the first part is to identify the group of countries with the lowest level of sales that is caused by chosen variables and to divide all of them into clusters to analyse their performance and response to macroeconomic changes. For this purpose, panel data analysis is used to find fixed effects for every country and to analyse the overall influence of independent variables on total sales. Moreover, cluster analysis allows to indicate a particular number of groups that connect similar countries by similar characteristics. The best-performing cluster can become a benchmark in terms of further comparison of these countries and their response to main macroeconomic conditions. In the second part of this section, the analysis focuses on car producers. The main idea is to find the best-performed group of automotive producers to explain their response to global financial changes and to find the optimal business strategy that allows achieving the highest market share on the European market or worldwide. Adequacy of these models are checked with main statistical tests and correspond to BLUE criteria while cluster analysis is additionally checked by Self-Organising Map tools.

3.1. Modelling and analysis of macroeconomic indicators influence on sales in European countries

In this part there is an analysis of the influence of main macroeconomic ratio on sales in 37 European countries for 2005-2019 years. The data file consists of yearly data of private cars sales from the open online recourse - carsalesbase.com. Additionally, main macroeconomic indicators were collected to analyse their possible influence on the level of sales in every investigated country and Europe. The description of these variables is in the table 3.1. below.

Table 3.1. Independent variables for the analysis

Variable	measure	Description	Source
GDP per capita	*USD*	A measure of the country's economic output accounts for its population	World Bank
Inflation	*Annual %*	A ratio of changings in the national price level	International Monetary Fund
Unemployment rate	*% of total labour force*	Percentage of currently unemployed inhabitants	International Labour Organization
Iron	*USD dry metric ton*	Crucial materials used in automotive industry	Trading Economics
Rubber	*U.S. Cents per Pound*		
Loan rate	*%*	Current loan rate to receive personal credit in the country	ECB
Saving ratio	*%*	A measure of national savings accounts for its population	OECD, local databases
Oil prices	*USD*	One of the most important components in automotive production and consumption	Bloomberg
Exchange to USD	*local currency units*	Indicates national currency stability	Local CBs
Dummy	-	1- switch to euro	
EURIBOR	*%*	A reference rate influences on all economic areas in Europe	ECB
SP500	*index*	The most crucial indexes on the market	finance.yahoo
EUROSTOX50	*index*		

Source: self-proceed by the author

For the analysis, 37 countries were chosen: Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, North Macedonia, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK.

Table 3.2. Summary of the Variables (rounded to 2 decimal places)

Variable	Mean	SD	Min	Max	Direction
GDP per capita	31000,00	25300,00	831,00	119000,00	+
Inflation	3,00	4,98	-4,48	59,20	-
Unem.rate	9,37	6,40	0,50	37,20	-
Iron	98,70	35,50	55,00	168,00	-
Rubber	108,00	50,30	53,70	250,00	-
Loan rate	5,61	4,58	0,02	26,90	-
Saving ratio	7,46	19,10	-64,00	125,00	+
Oil prices	72,10	19,00	43,60	99,70	-
Exchange to USD	19,30	47,10	0,21	327,00	-
Sales	400000,00	743000,00	600,00	3810000,00	dependent
EURIBOR	0,01	0,01	0,00	0,04	-
SP500	1720,00	595,00	948,00	2910,00	+
EUROSTOX50	3200,00	576,00	2120,00	4510,00	+

Source: self-proceed by the author

In addition to the main summary statistics of the selected variables, the possible directions of each of them are presented on the table above. The increases in GDP per capita, SP500 and EUROSTOX50 indicate the improvement of the economy that attracts potential buyers. Saving ratio demonstrates that an average customer has some extra money that can invest in the new car. At the same time, unemployment rate, loan rate and EURIBOR should have an opposite direction to the dependent variable. Similar situation with prices of iron, rubber and oil that are components of production costs that influence the final price of the vehicle. Finally, inflation and exchange rate can have positive or negative directions of influence because their increasing can stimulate inhabitants who hold national currency to spend it as soon as possible to avoid exchange losses.

To start modelling in *Gretl*, all chosen data has to be standardised and detrended to correspond to all main criteria of adequacy. In addition, there is a particular method of how to specify effects in the right way depends on the purpose of the analysis. In case, data is only a part of the total dataset, it is better to choose the panel data model with changing effects. In the case the chosen data represents all countries of the investigated region fixed effects are better for the modelling. However, such a model can have disadvantages because of the disability to estimate the influence of the factors that are constant and unchangeable within the boundaries of the panel. This problem can be ignored according to the real data that is not at risk. Finally, to eliminate the impact of not included variable for each country separately and to obtain unbiased parameter estimates, it is better to choose fixed effects for cross sections as well.

The final equation of the model:

$$ld\_Sales = const + \beta_1 ld\_EUROSTOX50 + \beta_2 d\_Loanrate + \beta_3 ld\_GDPpercapita + \beta_4 ExchangetoUSD + \beta_5 ld\_Iron(-1) + \beta_6 ld\_Rubber(-1) + \beta_7 ld\_Oilprices$$

Model 3.1. Fixed-effect panel data model for 37 countries

Fixed-effects, using 379 observations
Included 37 cross-sectional units
Time-series length: minimum 2, maximum 13
Dependent variable: ld_Sales

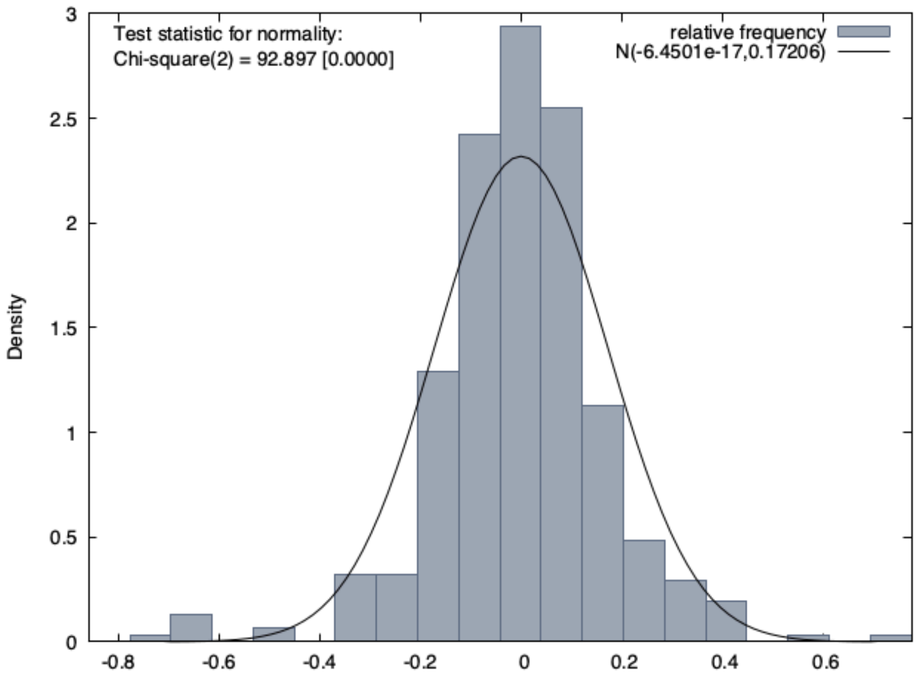
	Coefficient	Std. Error	t-ratio	p-value	
const	−0.124670	0.0317214	−3.930	0.0001	***
ld_EUROSTOX50	0.118839	0.0568633	2.090	0.0374	**
d_Loanrate	−0.0331826	0.00661517	−5.016	<0.0001	***
ld_GDPpercapita	1.17640	0.142676	8.245	<0.0001	***
ExchangetoUSD	0.00284586	0.00100951	2.819	0.0051	***
ld_Iron_1	−0.236266	0.0461932	−5.115	<0.0001	***
ld_Rubber_1	0.122328	0.0333868	3.664	0.0003	***
ld_Oilprices	−0.202597	0.0512866	−3.950	<0.0001	***

Mean dependent var	−0.001803	S.D. dependent var	0.234004
Sum squared resid	10.95419	S.E. of regression	0.180560
LSDV R-squared	0.470773	Within R-squared	0.699327
LSDV F(44, 336)	7.116388	P-value(F)	5.39e-27
Log-likelihood	133.7750	Akaike criterion	−181.5501
Schwarz criterion	−12.23601	Hannan-Quinn	−114.3588
rho	−0.138509	Durbin-Watson	2.127361

Source: self-proceed by the author

The constructed fixed-effect model corresponds all main tests and has relatively high R-squared ratio. To achieve the acceptable result of the Engle-Granger Test, investigated elements were detrended with logdif estimator. Some variables like Iron and Rubber were lagged by one year because the changings in their prices don't influence immediately according to the production cycle of the manufacturers. Also, the joint test on named regressors, Wald test and Chi-square show p-value less than 0,05 that is fine with the selected criteria of 95%. Finally, the test for differing group intercepts indicates the right choice to construct the model with fixed effects (don't have the same intercept).

Figure 3.1. Normal distribution of errors



Source: self-proceed by the author

P-value of F demonstrates that analysed coefficients differ from zero. Also, the Durbin-Watson test is close to 2 that indicates the absence of positive or negative autocorrelation. The presented in the model Schwarz, Akaike criterion, Log-likelihood and Hanna-Quinn are one of the best in comparison to other constructed models.

Figure 3.2. Autocorrelation intervals in the model

pos.autocor.	?	no autocorrelation	?	pos.autocor
1.7943	1.8693	2	2.1307	2.2057

Source: self-proceed by the author

As a result, the model shows the influence of EUROSTOX50, Loan rate, GDP per capita, the Exchange rate to USD and prices of iron, rubber and oil. Other economic variables that theoretically should influence on the number of sales in Europe doesn’t show any strong impact. Overall, the model explains changings in sales by chosen indicators on the level of almost 70%, other 30% are not included in the model. In terms of directions, EUROSTOX50 and GDP per capita have a positive influence as was expected. Loan rate, iron and oil prices reproduce the expected direction as well, while prices of rubber influence in a positive way. Another important point that the increase in exchange rate effect in the positive direction thus inhabitants of these European countries prefer to spend more and buy cars during the period of a recession of the national currency.

In terms of coefficients, GDP per capita, Iron and Rubber prices have the biggest impact on sales in investigated European countries (29,13%, 22,63% and 19,48% respectively). The exchange to USD has the smallest impact on the level of 3,41%. As a result, the most crucial issue here is an influence of rubber because it doesn't match theoretical direction and have a strong influence. This should be taken under consideration in terms of further forecasting of sales in Europe.

Table 3.3. IQ range and influences of coefficients

Variable	IQ range	est coeff	IQR *	abs	Impact
ExchangetoUSD	6,1081	0,00284586	0,0173828	0,0173828	3,41%
EUROSTOX50	0,31151	0,118839	0,03701954	0,03701954	7,26%
Loanrate	1,0156	-0,0331826	-0,0337002	0,03370025	6,61%
GDPpercapita	0,12619	1,1764	0,14844992	0,14844992	29,13%
Iron	0,48816	-0,236266	-0,1153356	0,11533561	22,63%
Rubber	0,81145	0,122328	0,09926306	0,09926306	19,48%
Oilprices	0,2886	-0,202597	-0,0584695	0,05846949	11,47%
			sum=	0,50962066	

Source: self-proceed by the author

From Table 3.3 Latvia has the smallest level of sales without any influence of the selected indicators therefore this country needs to adjust all connected risks respectively. Moreover, three of V4 countries (Poland, Czechia and Slovakia) are in the first part of the list and demonstrates high level of car purchasing despite changes of selected macroeconomic variables. Bosnia and Herzegovina has the highest value of fixed effects that can be explained by national specificities of small number of potential customers, high purchasing rate of already used cars and financial recession with fiscal problems 5 years ago.

Table 3.4. Fixed effects for every investigated country

Country	Effect	Country	Effect
Bosnia and Herzegovina	0,1773	UK	0,0036
Poland	0,1092	Belgium	0,0034
Belarus	0,0978	Germany	0,0030
Albania	0,0632	Netherlands	-0,0063
Slovakia	0,0417	Bulgaria	-0,0124
Iceland	0,0398	Hungary	-0,0133
Denmark	0,0371	Italy	-0,0149
Czechia	0,0359	Croatia	-0,0172
Norway	0,0204	Spain	-0,0201
Sweden	0,0177	Romania	-0,0355
Moldova	0,0175	Ireland	-0,0387
Slovenia	0,0159	Cyprus	-0,0519

Table 3.4. Fixed effects for every investigated country (continuation)

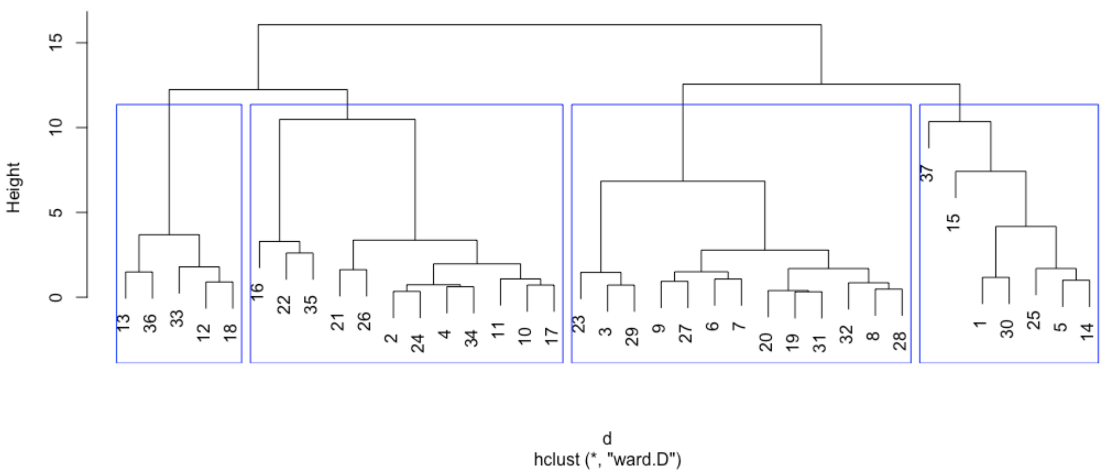
Malta	0,0135	Ukraine	-0,0524
Switzerland	0,0111	Finland	-0,0602
France	0,0078	North Macedonia	-0,0905
Luxembourg	0,0061	Portugal	-0,1401
Austria	0,0050	Lithuania	-0,1727
		Latvia	-0,9046

Source: self-proceed by the author

This set of data is used for cluster analysis performed in *RStudio*. In the previous model, the local (national) indicators were used together with global ones, however, for this analysis, it is better to use only national ratios to identify a few clusters with the most similar countries and analyse how they are affected by changes in the local economy.

In *RStudio* three possible cluster models were constructed: k-means with 3 and 5 clusters and dendrogram clustering with 4 clusters are presented in Appendix 2, 3 and 4. As a result, the last one was chosen to determine and analyse these differences.

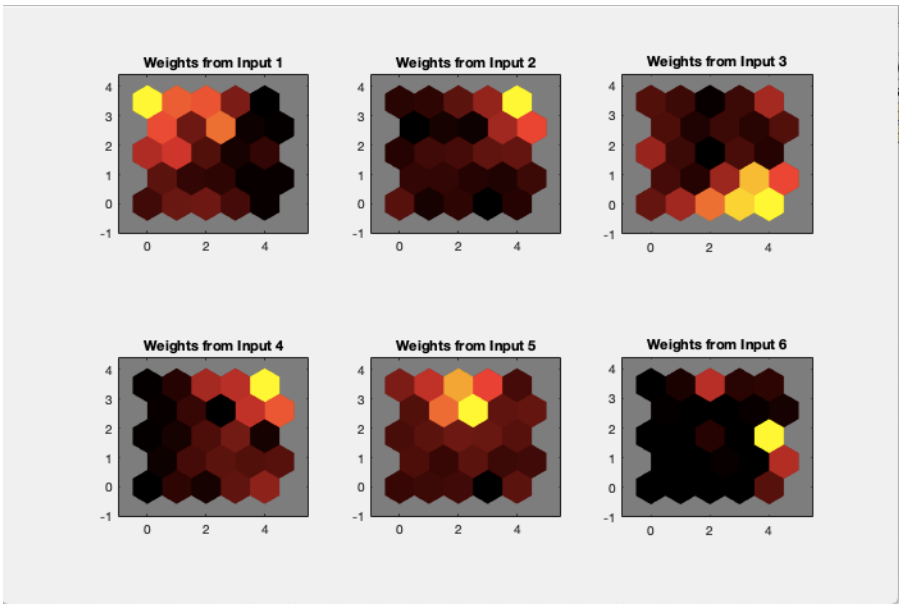
Figure 3.3. Cluster Dendrogram for 37 investigated countries



Source: self-proceed by the author

For this analysis Ward's method that minimizes the increase in the total within-cluster sum of squared error and is based on Euclidean distance is used. Additionally, the level of correlation between selected characteristics that form clusters is investigated by Self Organizing Maps in *MatLab*.

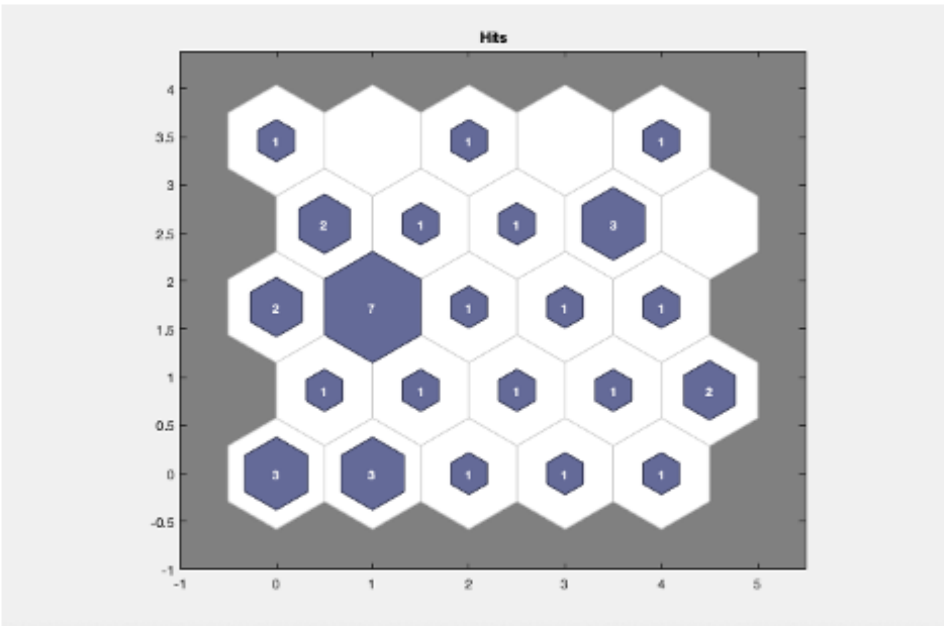
Figure 3.4. SOM Weights for selected inputs



Source: self-proceed by the author

For this purpose, 5 neurons are chosen for testing, which is the optimal number based on a small amount of investigated countries. The higher number will dissipate 37 elements that make clustering impossible. Also ,200 epochs are chosen as a standard for this type of analysis. The result of 6 chosen variables (without sales) for clustering demonstrates an absence of the critical level of correlation between these independent variables.

Figure 3.5. Hits of 37 countries in MatLab SOM Neural Networks



Source: self-proceed by the author

From Figure 3.5. it is possible to indicate 4 clusters that were determined by dendrogram earlier. As a result, the countries with own specificities are divided into 4 groups that are presented on the table below.

Table 3.5. Dendrogram clustering with 4 groups for European countries

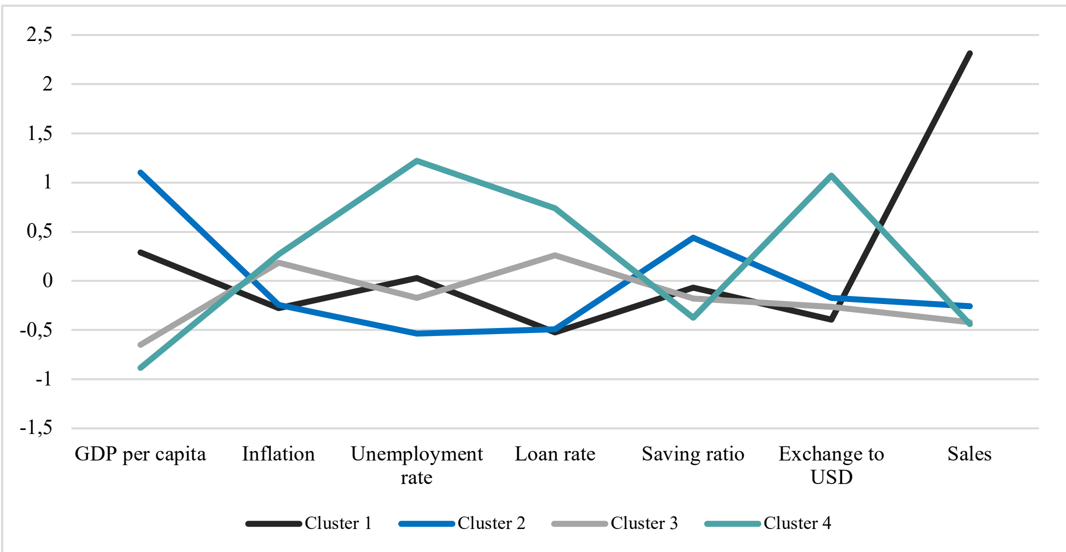
Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Germany, UK, France, Italy, Spain	Austria, Belgium, Denmark, Finland, Ireland, Luxembourg, Netherlands, Norway, Sweden, Iceland, Malta, Switzerland	Cyprus, Czechia, Latvia, Lithuania, Poland, Portugal, Slovakia, Slovenia, Bulgaria, Croatia, Belarus, Moldova, Romania	Albania, Bosnia and Herzegovina, Greece, Hungary, North Macedonia, Serbia, Ukraine

Source: self-proceed by the author

A first cluster has 5 well-developed, politically active countries of Europe, while a second one consists of 12 relatively good-performed countries with high economic development and living standards. Countries that recently joined the European Union and have been under communist rules before form third cluster with 13 countries. The worst developed countries in the investigated group that have some financial problems are consolidated in the last cluster.

However, the most important part of such analysis is the distribution of means of every indicator for each cluster that is presented on the figure below.

Figure 3.6. Means of selected indicators for each cluster



Source: self-proceed by the author

Cluster 1 consists of the best-developed countries in Europe with the highest level of automotive sales. The average sales in these countries in 12-27 times higher in comparison with other clusters. The population of the divided into clusters countries has a strong influence, higher consumption market leads to a higher level of sales. However, these groups also have some macroeconomic indicators that affect and allocate them.

Cluster 1**:** these countries have high GDP per capita, the lowest inflation, loan rate and the more stable local currency (4/5 are in the eurozone). Also, they have an average amount of unemployment rate and saving rate. This demonstrates that maximum and minimum values of variables with positive and negative influence respectively doesn't guarantee the best performance in sales.

Cluster 2**:** selected countries have the highest GDP per capita that can be caused by North countries with high amounts of GDP and comparatively smaller population. The cluster has the smallest inflation, unemployment and loan rate with the highest saving ratio mostly caused by Switzerland and Luxembourg.

Cluster 3**:** these countries have low GDP per capita, saving ratio and an average unemployment rate. Their inflation and loan rates are pretty high that negative effects on the total level of sales. However, their local currencies are stable that causes more sales in comparison with the last cluster. Most of these states recently became independent and has only 30 years to rebuilt economy after communist rules.

Cluster 4**:** this group has the worst values of the main indicators and demonstrate the lowest amount of sales during the investigated period. Their main specificities are high unemployment rate and unstable local currency that stimulates people to spend money quickly with decreasing saving ratio. Also, some of these countries had a financial crisis during the last years and unstable national economies in general.

To sum up, in this part the panel data model with fixed effects are constructed in *Gretl* that allows analysing the position of V4 countries and general influence of some macroeconomic indicators on the level of automotive sales in European countries. Moreover, not every theoretical assumption is confirmed that demonstrate the importance of such analysis to adapt and take into account all possible risks. Additionally, selected 37 countries are divided into 4 clusters by cluster analysis in *RStudio* and *Matlab*. This allows to define the best-performing countries and analyse every macroeconomic indicator that involved. Despite some outliers and national specificities, the analysis demonstrates the important role of particular macroeconomic factors and their combinations to set up adequate customer market of the automotive industry.

3.2. Modelling and analysis of global macroeconomic indicators influence on main producers of the private cars on the European market.

In this part, there is an analysis of the response of main automotive producers on the European market to changes of global macroeconomic indicators. For such model yearly data of sales of 14 personal car producers during 2000 – 2019 years were chosen: BMW Group, Daimler AG, FCA Group, Ford Motor Company, Geely Group, General Motors Europe, Group PSA, Hyundai Motor Group, Mahindra & Mahindra, Proton / DRB-Hicom, Renault-Nissan Group, Tata Motors, Toyota Motor Corporation, Volkswagen Group. This data was collected from the same open online recourse - *carsalesbase.com*. Some global indicators such as iron and oil prices, EUROSTOX50, GDP per capita and lending rate. However, some new indicators like CPI, Rail lines, EUR/USD exchange rate and Households' consumption were added additionally. CPI indicates the weighted average of prices of a basket of consumer goods and services. Railway network demonstrates the level of development of railway infrastructure in selected countries. In the case of poor development, households have a higher demand for personal cars to be able to move around. An exchange rate represents the stability of the main currency in Europe in response to the US dollar. Finally, PPP demonstrates price level differences across chosen countries and can show how cointegration influence on automotive producers.

Table 3.6. Independent variables for the analysis

Variable	measure	Description	Source
GDP per capita	*USD*	A measure of the country's economic output accounts for its population	World Bank
CPI	*2010=100*	A ratio of changings in the national price level	International Monetary Fund
Unemployment rate	*% of total labour force*	Percentage of currently unemployed inhabitants	International Labour Organization
Iron	*USD dry metric ton*	Crucial materials used in automotive industry	Trading Economics
Lending interest rate	*%*	Average loan rate to receive personal credit	International Monetary Fund
Oil prices	*USD*	One of the most important components in automotive production and consumption	Bloomberg
EUR/USD	*amount of euro per one dollar*	Indicates local currency stability	ECB

Table 3.6. Independent variables for the analysis (continuation)

EUROSTOX50	*index*	Indicates the overall economic performance	yahoo.finance
PPP	*currency units per dollar*	Indicates differences in purchasing poverty across countries	eurostat
Rail lines	*Total route-km*	Sum a total amount of rail lines in the region	Internation Union of Railways

Source: self-proceed by the author

All these statistics represent the following countries: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland.

Table 3.7. Summary of the Variables (rounded to 2 decimal places)

Variable	Mean	SD	Min	Max	Direction
GDP per capita	984384,42	229637,14	531242,7511	1294790,26	+
CPI	96,95	12,48	74,96	114,08	-
Unemployment rate	8,74	1,23	6,30	10,80	-
Iron	81,65	43,69	28,00	168,00	-
Lending interest rate	7,22	3,18	2,39	14,25	-
Oil prices	61,82	25,00	25,98	99,67	-
EUR/USD	0,84	0,124	0,68	1,11	-
EUROSTOX50	3307,33	774,06	2118,94	5175,00	+
PPP	0,78	0,06	0,69	0,88	+
Rail lines	16401,51	2718,45	13085,56	19860,55	-

Source: self-proceed by the author

In addition to the main summary statistics of the selected variables, the possible directions of each of them are presented on the table above. The increase in GDP per capita and EUROSTOX50 indicates the improvement of the European economy that theoretically increase the income of householders and attracts potential buyers. The increasing of PPP and its drawing near 1 means equalisation of nationals' welfare. It improves general economic conditions in more poor countries in the region and can increase the number of potential buyers. Higher inflation, unemployment and lending interest rates together with euro depreciation negatively influence on the purchasing power of householders. Iron and oil prices increase operational costs of production and increase prices of cars that decrease potential sales. The decreasing in the total amount of rail route-km stimulates to buy own cars to be able to move around. Some countries increase rail lines to decrease car consumption and CO2 emission.

To proceed cluster analysis of 14 producers on the selected market 14 simple pooled OLS models have to be constructed. To start modelling in *Gretl*, all chosen data has to be standardised and detrended to correspond to all main criteria of adequacy. In this case panel data with fixed effects can't be used according to tests for differing group intercepts. As a result, the constructed table below consists of percentages of selected indicators' influences on every automotive brand.

The general equation of the models:

$$\begin{aligned} ld\_brand = const + \beta_1 ld\_EUROSTOX50 + \beta_2 d\_Loanrate + \beta_3 ld\_GDPpercapita \\ + \beta_4 EURUSD + \beta_5 ld\_Iron(-1) + \beta_6 d\_unemploymentr(-1) \\ + \beta_7 ld\_Oilprices + \beta_8 d\_PPP + \beta_9 d\_CPI + \beta_{10} ld\_Rail(-1) \end{aligned}$$

Table 3.8. Influences of macro indicators on selected producers' sales

	Iron	Oil	EUROSTOX50	EUR/USD	Unemployment	PPP	CPI	GDP per capita	Lending rate	Rail lines
1	0,03%	0,04%	0,83%	14,64%	0,49%	55,02%	4,70%	19,78%	4,46%	0,00%
2	0,02%	0,01%	1,81%	11,98%	0,71%	35,21%	32,28%	15,48%	2,49%	0,00%
3	0,01%	0,02%	0,45%	23,98%	1,56%	12,63%	27,34%	30,59%	3,43%	0,00%
4	0,00%	0,00%	0,04%	29,91%	0,16%	36,60%	3,13%	28,96%	1,20%	0,00%
5	0,02%	0,12%	0,89%	2,55%	0,05%	43,43%	17,87%	29,22%	5,85%	0,00%
6	0,01%	0,03%	0,09%	15,02%	0,52%	35,36%	30,49%	15,52%	2,96%	0,00%
7	0,01%	0,01%	0,05%	18,89%	1,00%	29,18%	29,57%	17,71%	3,58%	0,00%
8	0,03%	0,04%	1,77%	9,47%	0,14%	47,05%	25,04%	13,26%	3,20%	0,00%
9	0,00%	0,02%	0,75%	21,84%	0,81%	29,80%	22,22%	19,91%	4,63%	0,00%
10	0,00%	0,04%	0,69%	22,54%	1,12%	22,85%	28,21%	18,74%	5,81%	0,00%
11	0,01%	0,06%	2,24%	31,80%	0,40%	7,66%	25,33%	27,91%	4,59%	0,00%
12	0,02%	0,04%	1,52%	16,83%	0,85%	31,70%	35,08%	10,84%	3,11%	0,00%
13	0,00%	0,01%	0,10%	1,84%	0,21%	27,93%	59,56%	10,00%	0,34%	0,00%
14	0,05%	0,12%	11,56%	0,57%	0,17%	31,18%	36,97%	14,64%	4,75%	0,00%

Where 1-BMW Group, 2-Daimler AG, 3-FCA Group, 4-Ford Motor Company, 5-Geely Group, 6-General Motors Europe, 7-Group PSA, 8-Hyundai Motor Group, 9-Mahindra & Mahindra, 10-Proton / DRB-Hicom, 11-Renault-Nissan Group, 12-Tata Motors, 13-Toyota Motor Corporation, 14-Volkswagen Group

Source: self-proceed by the author

From the table above, it is possible to determine the most and the less affected companies by a particular factor. Mahindra & Mahindra and Proton / DRB-Hicom are less effected by changings at prices of iron, while the German Volkswagen Group relatively has the biggest influence. In terms of oil price, Volkswagen Group together with Geely Group has the biggest impact on their sales, while the smallest influence on sales companies like Toyota Motor Corporation, Daimler AG and Group PSA have. As a result, German Volkswagen Group's sales depends up to 0,17% on the world price of natural recourses.

General economic conditions reflected in EUROSTOX50, GDP per capita and EUR/USD strongly influence almost every automotive producer. Already mentioned Volkswagen Group is strongly dependent on stock price index and almost independent on euro stability. Renault-Nissan Group that recently created an Allianz with Mitsubishi is strongly dependent on euro currency stability that is the main macroeconomic indicators with such level of influence. This can be explained by close interactions between international partners outside Europe and possible transaction expenses generated by exchange rate fluctuations. Finally, GDP per capita is one of the most important macroeconomic indicators for every company that is proven by such percentages.

CPI and PPP are ones of the most important elements as well. For instance, BMW Group depends on PPP on the level of 55% that is more than half of the total influence of investigated indicators. This producer is the most interested in equalization of the purchase power and improvement of national economical conditions in less developed countries in Europe. Moreover, sales of Toyota Motor Corporation are strongly depended on CPI that indicate the level of inflation in the European region.

The lending interest rate that should strongly effect on the potential buyer's decision based on the possibility of car loans doesn't have an expected level of influence. However, producers like BMW Group, Geely Group, Mahindra & Mahindra, Renault-Nissan Group and Volkswagen Group are the most depended that indicate their higher prices for the selected segment of consumers in comparison to competitors and a necessity of loan to be able to buy such a car.

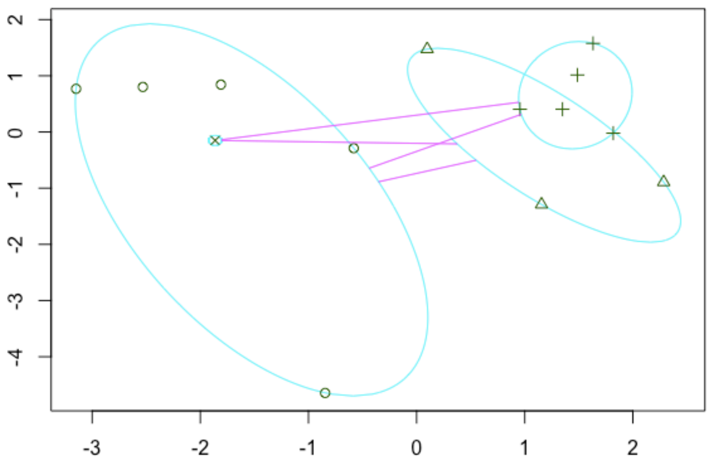
Finally, rail lines have a weak influence on such brands while the unemployment rate is one of the important factors for FCA Group and Group PSA that are reasonably priced car for households with a medium level of income.

3.3. Cluster analysis of the 14 brands based on their response to selected macroeconomic indicators

The cluster analysis is proceeded according to the results in the table above and aims to divide automotive producers into some clusters based on their dependence on selected global indicators.

Three possible cluster models are constructed in *RStudio*: k-means with 3 and 4 clusters and dendrogram clustering with 4 clusters are presented in Appendix 5 and 6. The last two of them show the same results therefore it is possible to assume that the optimal structure for this dataset is 4 clusters. This structure is also chosen to determine and analyse differences between groups.

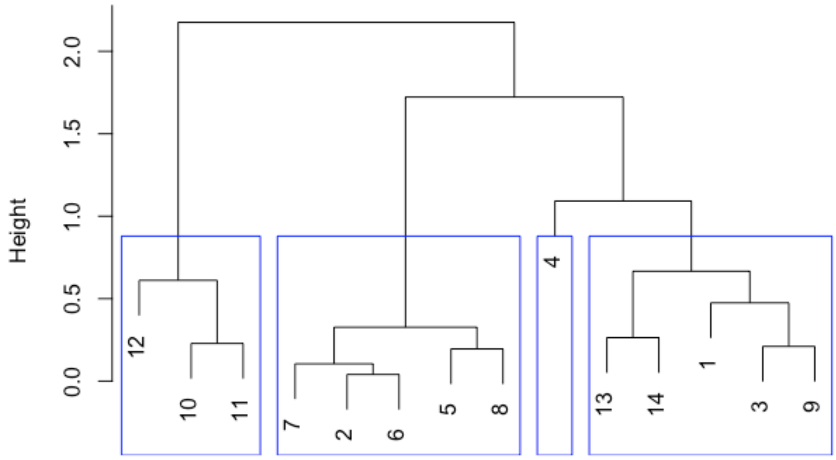
Figure 3.7. 2D representation of clusters



Source: self-proceed by the author, RStudio

The picture represents only two main indicators that have the biggest influence in terms to divide the selected brands into 4 clusters. That is why the representation demonstrates only 53% of explanation and demonstrates only 3 clusters that landed on 2D representation.

Picture 3.8. Cluster Dendrogram for 14 investigated brands

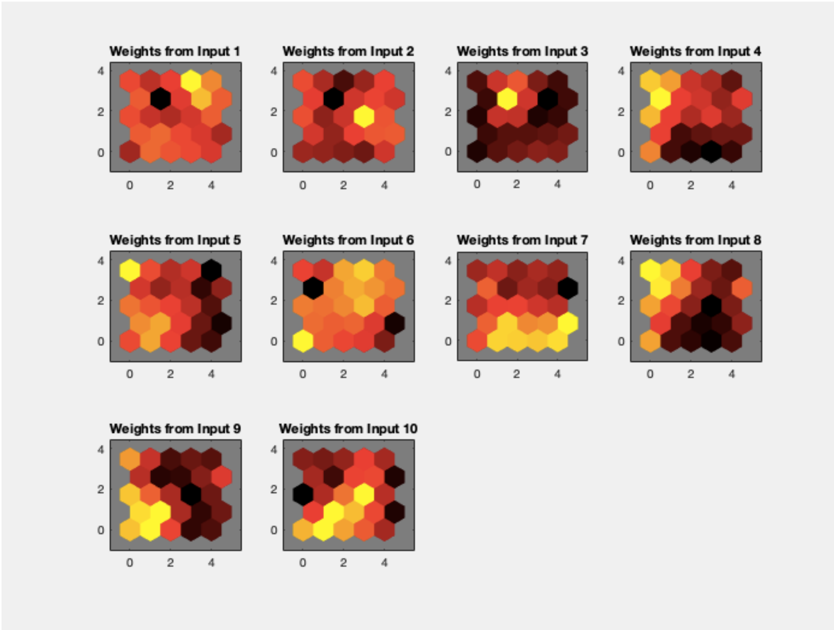


Source: self-proceed by the author, RStudio

Ward's method that is used in the model, minimises the increase in the within-cluster sum of squared error and is based on Euclidean distance. Moreover, from the representation is possible to confirm that 14 investigated brands form 4 groups. Notably, 4th brand form own cluster that can be explained by the American origin of the producer.

Additionally, the level of correlations between selected characteristics that form clusters were investigated by Self Organizing Maps in *MatLab*. For this purpose, 4 neurons are chosen for testing, which is the optimal number based on a small number of investigated brands. The higher number will dissipate 14 elements that make clustering impossible. Also, 200 epochs are chosen as a standard for this type of analysis. The result of 6 chosen variables (without sales) for clustering demonstrates an absence of the critical level of correlation between these independent variables.

Figure 3.9. SOM Weights for selected inputs



Source: self-proceed by the author, MatLab

Table 3.9. Dendrogram and k-means clustering with 4 groups for producers

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Proton / DRB-Hicom Renault-Nissan Group Tata Motors	BMW Group FCA Group Mahindra&Mahindra Toyota Motor Corporation Volkswagen Group	Ford Motor Company	Daimler AG Geely Group General Motors Europe Group PSA Hyundai Motor Group

Source: self-proceed by the author

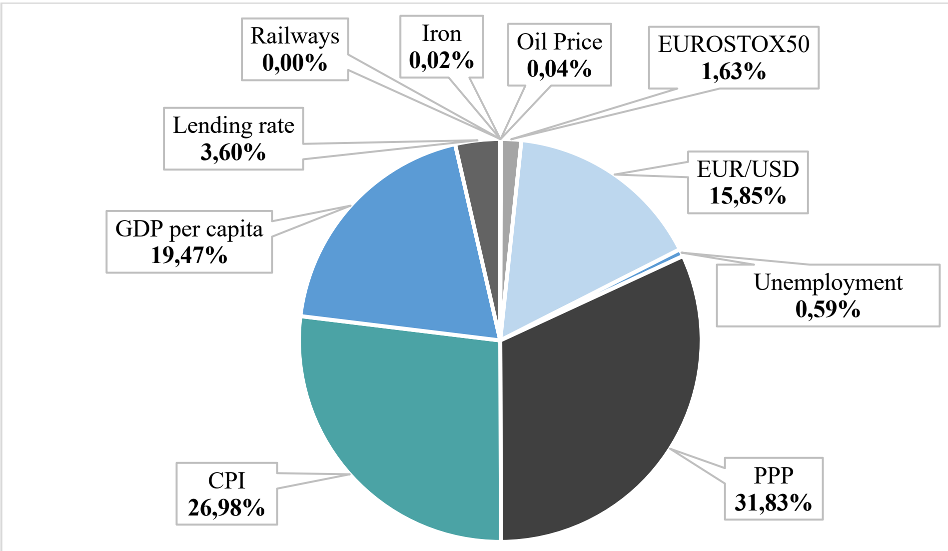
A first cluster consists of 3 companies with average prices on the market mostly oriented to mass-market customers. DRB-Hicom and Tata Motors are Malaysian and Indian companies that offer basic cars with smaller than average price. At the same time, Renault-Nissan Group is a European company with average prices on passenger cars. However, these companies have additional subsidiaries that specialise on the luxury market and make the investment in new technologies. For instance, Tata Motors has Jaguar Land Rover and Renault-Nissan Group is a pioneer of eco-friendly electric cars.

The second cluster consists of 5 the most popular mass vehicles that have a bigger price in comparison with competitors. Also, these producers have a lot of luxury cars that are popular in the selected region. At the same time, American Ford Motor Company forms own cluster and have many differences in case of macroeconomic indicators' influence.

The last cluster consists of 5 producers and combines a little bit different companies based on their main segment. One of the questions is why Daimler AG was placed in the last cluster, not in the second one.

However, the most important part of an such analysis is the distribution of means for each cluster. On the graph below the average influence of the selected macroeconomic indicators is presented. This information gives the opportunity to focus more on the most important indicators that have the biggest positive or negative influence.

Figure 3.10. Average influence on selected automotive brands



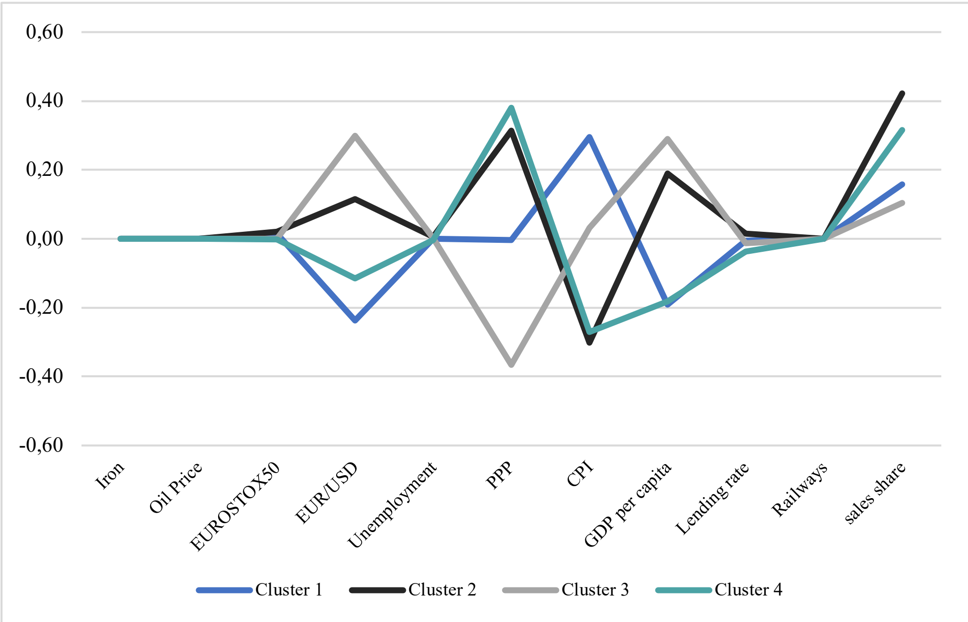
Source: self-proceed by the author

The result demonstrates the big influence of PPP, CPI, GDP per capita and EUR/USD. All these approve the fact that economic conditions of all countries in the region influence on automotive sales. The most questionable and experimental variable PPP that was used during such analysis shows the biggest influence. Since the main assumption was the poorer countries become richer and extend the ratio to 1, this is corresponding to the necessity to improve national welfare in such countries to receive more potential buyers. Also, it is remarkable that oil and iron prices that influence on automotive prices don't strongly impact on householders' decisions.

The following analysis of defined clusters and their specificities approve the low influence of iron and oil prices, EUROSTOX50 index and rail lines across the countries. Therefore, it is better to focus on the biggest effects to define the crucial differences between clustered brands.

Also, together with averages of indicators' effects determined by 14 pooled OLS models, total market shares of these clusters are marked on the graph.

Figure 3.11. Means of effects for each cluster



Source: self-proceed by the author

***Cluster 1*:** The automotive producers of the cluster has a negative response in sales to euro appreciation. Also, a higher level of inflation increases sales of this group of companies that can be explained by its mass-market feature in the less developed countries (Cluster 4 from the previous cluster analysis).

***Cluster 2*:** This group of companies have a positive effect of euro depreciation that doesn't follow theoretical assumption however it can be explained by relative decreasing in the price for consumers during euro depreciation caused by less elastic final prices. PPP, CPI and GDP per capita are in response to all main theory. Moreover, this cluster has the highest share of the market.

***Cluster 3*:** The company has high impacts of euro depreciation and GDP per capita ration in a positive direction. However, the highest negative impact is based on PPP demonstrates that sales decrease during the increasing of PPP and improvement of welfare across the countries. The positive influence of CPI can be explained by the non-EU origin and fixed prices on a short-term perspective. Since this is the only company in the cluster, the total amount of sales and market share is the lowest one.

***Cluster 4*: These companies differ by the biggest influence of the lending interest rate. Like a first cluster, they have negative influence of GDP per capita increasing. However, the group has theoretically a logical response to PPP and CPI that have high effects on sales. Additionally, Daimler AG that is a part of the cluster confirms its dependence on cointegration level in Europe. As a result, the increasing in sales of the company is connected to improvements of national economics in less-developed countries.

In the previous figure the information about the total market share of every cluster are presented, but to determine the best performing one it is necessary to analyse average market share per company.

Table 3.10. Average market share per brand during 2000-2019

Company	Cluster	Market share	Av. Cluster
Ford Motor Company	1	10,3%	10,3%
BMW Group	2	6,5%	
FCA Group	2	4,3%	
Mahindra & Mahindra	2	0,0%	8,5%
Toyota Motor Corporation	2	5,7%	
Volkswagen Group	2	25,7%	
PROTON / DRB-HICOM	3	0,0%	
Renault-Nissan Group	3	15,1%	5,3%
Tata Motors	3	0,7%	
Daimler AG	4	6,3%	
Geely Group	4	0,0%	
General Motors Europe	4	8,8%	6,3%
Group PSA	4	15,3%	
Hyundai Motor Group	4	1,0%	

Source: self-proceed by the author

Volkswagen Group, Group PSA and Renault-Nissan Group have the biggest market share on the European market; however, American Ford Motor Company is right behind them. It is possible to confirm that the effects by analysed before indicators don't have any correlation with the market share of the company. That means some macroeconomic events can differently impact the biggest market players in Europe. Additionally, it is difficult to adequately determine in which cluster the best performed by sales companies are allocated.

To sum up, in this part the cluster analysis of already modelled effects is proceeded in *RStudio* and *MatLab* to divide 14 brands of the automotive industry on the European market into some groups with own specificities. This allocation into 4 clusters demonstrates that not every producer follows the theoretic assumptions in terms of macroeconomic indicators' influence. However, some brands indicate additional patterns that have to be used to estimate all possible risks properly. Overall, considering some individual characteristics the analysis demonstrates an important role of macroeconomic factors despite the company's originality, location of the main office or currency used in main activities.

CONCLUSION

In this master thesis, the automotive market in Europe and the influence of various macroeconomic indicators are analysed. In the first section, the literature overview was presented to identify the most important and common used economic indicators that have been used by other researches in a similar analysis of the automotive industry. Also, these articles and papers were used to determine the methodology that is common in such an analysis. The main tendencies on the European market, non-financial indicators, environmental regulation and future challenges were analysed in the section as well. Additionally, it was confirmed the importance of the industry in the national economy of many European countries where up to 15.4% of the population is directly involved and up to 50% of national GDP are dependent. Moreover, the industry represents more than 8% in average of total national revenues in the region and around 5% of total EU export.

One of the biggest problems of the manufacturers in the selected region is lower profits because of the high level of competition on the market, new environmental regulations and political, trading risks. During the analysis, another important factor of purchasing power and its differences by regions were described as an additional factor than influence many automotive producers.

According to the estimated reduction in production in response to COVID-19 the European producers are going to decrease the total number by 5.1%. At the same time, new passenger car registration is going to decrease in 4 times during the first quartal of the current year.

Also, it was confirmed that the European market is not the biggest one in the world, however, it has the biggest amount of R&D, innovative ecological and luxury solutions. This is caused by the strict regulation of the European government.

Besides, the analysis of European manufacturers demonstrated the high popularity of the Volkswagen Group and Renault–Nissan Association in terms of total sales in the selected countries.

The econometric analysis is the most important part of the master thesis. As a result, the final dataset consists of GDP per capita, inflation, unemployment rate, prices on iron, rubber and oil, loan rates, saving ratios, two exchange stocks, the interest rate that can influence on the total number of sales. Additionally, some statistic was added during the modelling to increase the level of adequacy.

According to the constructed panel data model the countries with the smallest level of sales without any influence of macroeconomic indicators were determined. Latvia, Lithuania, Portugal and North Macedonia demonstrated the high dependence on the selected factors. At the same time, Visegrad countries that are one of the best-developing in terms of car production showed high levels of purchasing despite the economical changes.

All these countries were divided into 4 clusters that group according to national specificities and individual characteristics.

Also, in the third section, similar global indicators were used to analyse the influence on all manufacturers present in Europe. As a result of simple OLS models, the matrix with influences of every indicator on every producer was built. This allowed analysing which company was less or more dependent on the particular macroeconomic factor during the investigated period. Therefore, general economic conditions reflected in EUROSTOX50, GDP per capita and EUR/USD strongly influence almost every automotive producer. For instance, Renault-Nissan Group that recently created an Allianz with Mitsubishi is strongly dependent on euro currency stability that is the main macroeconomic indicators with such level of influence. This can be explained by close interactions between international partners outside Europe and possible transaction expenses generated by exchange rate fluctuations. Also, BMW Group was determined as the most dependent in terms of purchasing power differences by countries, therefore, is the most interested in equalization and improvement of national economic conditions in less developed countries in Europe. Finally, the prices of natural resources demonstrated the highest influence on total sales of Volkswagen Group.

These results were additionally used in further cluster analysis with integration to Self-Organising Maps and a neural network. As a result, the investigated companies were divided into 4 clusters. Not every cluster was performed according to the main theoretic hypothesis. Considering some individual characteristics, the analysis demonstrates an important role of macroeconomic factors despite the company's originality, location of the main office or currency used in main activities. As an example, Ford Motor Company that is one of the leaders in the world and has a strong presence on the European market was allocated into the separate group. At the same time, the second cluster was determined as a best-performing one and consists of BMW Group, FCA Group, Mahindra & Mahindra, Toyota Motor Corporation, Volkswagen Group.

The last analysis of the influence on all automotive industry in Europe demonstrated the importance of CPI, cointegration of all countries in the region, GDP per capita and an exchange rate of EUR to USD.

To sum up, this master thesis described the automotive industry in the European countries with main tendencies, challenges, risks and opportunities that can be useful for automotive manufacturers and any market players. The results demonstrated the importance of macroeconomic indicators in sales forecasting and general estimations in the company's performance. It is proved that automotive producers are one of the most important parts of the European economy and is also influenced by macroeconomic stability.

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Annexes

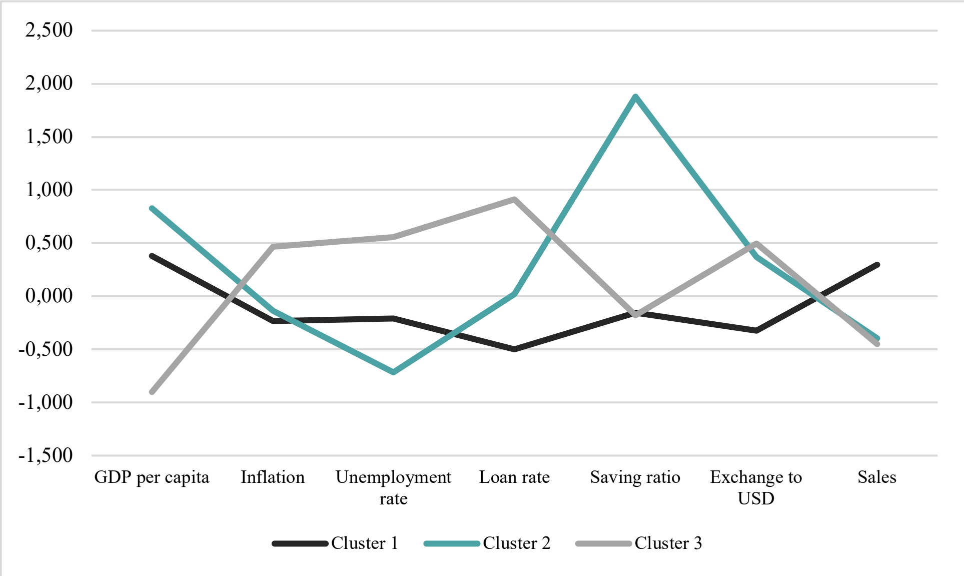
Appendix 1. Standardised data from the cluster analysis (rounded to 2 decimal places)

Country	GDP per capita	Inflation	Unempl. rate	Loan rate	Saving ratio	Exchange to USD	Sales
Albania	-1,06	-0,13	0,78	1,05	-0,18	1,83	-0,54
Bosnia	-1,03	-0,26	2,56	0,18	-0,47	-0,38	-0,52
Greece	-0,30	-0,31	1,24	0,53	-0,91	-0,39	-0,34
Hungary	-0,68	0,07	-0,28	0,11	-0,06	4,53	-0,39
N.Macedonia	-1,03	-0,23	3,10	0,73	-0,20	0,63	-0,53
Serbia	-0,98	0,72	1,35	0,01	-0,50	1,38	-0,50
Austria	0,65	-0,23	-0,66	-0,55	0,09	-0,39	-0,11
Belgium	0,52	-0,22	-0,28	-0,68	0,03	-0,39	0,16
Denmark	1,07	-0,30	-0,57	-0,75	-0,33	-0,28	-0,30
Finland	0,64	-0,31	-0,22	-0,73	-0,38	-0,39	-0,38
Ireland	1,12	-0,38	-0,01	-0,43	-0,16	-0,39	-0,38
Luxembourg	2,98	-0,23	-0,64	-0,75	0,33	-0,39	-0,47
Netherlands	0,76	-0,28	-0,65	-0,75	-0,03	-0,39	0,07
Norway	2,12	-0,18	-0,91	-0,60	-0,08	-0,26	-0,36
Sweden	0,88	-0,36	-0,33	-0,73	0,20	-0,25	-0,13
Cyprus	-0,10	-0,35	-0,06	0,05	-0,35	-0,39	-0,52
Czechia	-0,45	-0,18	-0,62	-0,14	0,05	0,04	-0,27
Latvia	-0,67	0,16	0,24	-0,33	-0,80	-0,40	-0,52
Lithuania	-0,66	0,01	0,03	-0,40	-0,49	-0,37	-0,51
Poland	-0,72	-0,20	-0,11	-0,23	-0,36	-0,36	-0,07
Portugal	-0,37	-0,32	0,15	-0,24	-0,39	-0,39	-0,31
Slovakia	-0,55	-0,18	0,34	-0,58	-0,30	-0,25	-0,44
Slovenia	-0,30	-0,24	-0,38	-0,52	-0,12	0,15	-0,46
Iceland	1,00	0,36	-0,80	1,24	-0,05	1,89	-0,52
Malta	-0,31	-0,23	-0,58	-0,29	0,95	-0,39	-0,53
Switzerland	1,79	-0,53	-0,77	-0,90	4,73	-0,39	-0,14
Bulgaria	-0,94	0,11	-0,12	0,60	-0,09	-0,38	-0,50
Croatia	-0,69	-0,22	0,43	0,55	0,07	-0,28	-0,47
Germany	0,48	-0,31	-0,50	-0,57	0,15	-0,39	3,77
UK	0,49	-0,16	-0,55	-0,61	-0,20	-0,40	2,57
France	0,37	-0,35	-0,06	-0,70	0,08	-0,39	2,24
Italy	0,15	-0,31	0,02	-0,23	-0,15	-0,39	2,01
Spain	-0,06	-0,26	1,24	-0,51	-0,23	-0,39	0,98
Belarus	-0,99	2,77	-1,03	1,53	0,23	-0,39	-0,50
Moldova	-1,14	0,86	-0,66	1,98	0,46	-0,11	-0,53
Romania	-0,86	0,18	-0,48	1,11	-0,22	-0,34	-0,35
Ukraine	-1,11	2,05	-0,20	2,55	-0,32	-0,13	-0,23

Source: self-proceed based on the initial datasets

Appendix 2. Means of macroeconomic indicators (k-means, 3)

(rounded to 3 decimal places)



Source: self-proceed by the author

Cluster	GDP per capita	Inflation	Unempl. rate	Loan rate	Saving ratio	Exchange to USD	Sales
Cluster 1	0,379	-0,235	-0,206	-0,500	-0,157	-0,322	0,300
Cluster 2	0,826	-0,137	-0,716	0,018	1,879	0,369	-0,397
Cluster 3	-0,902	0,466	0,558	0,912	-0,182	0,499	-0,451

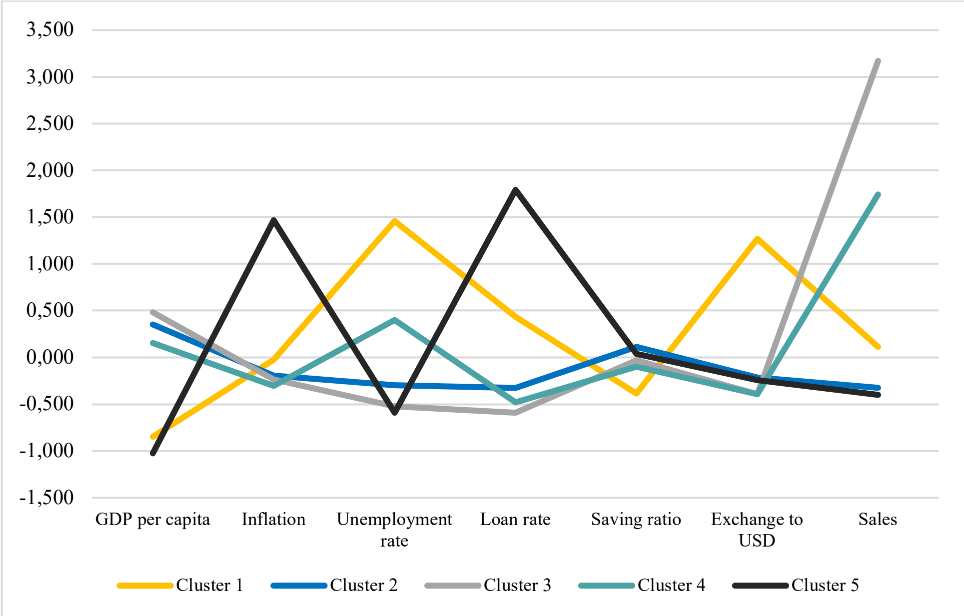
Source: self-proceed by the author

Cluster 1: Austria, Belgium, Cyprus, Czechia, Denmark, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, UK.

Cluster 2: Iceland, Malta, Switzerland.

Cluster 3: Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Moldova, North Macedonia, Romania, Serbia, Ukraine.

Appendix 3. Means of macroeconomic indicators (k-means, 5) (rounded to 3 decimal places)



Source: self-proceed by the author

Cluster	GDP per capita	Inflation	Unempl. rate	Loan rate	Saving ratio	Exchange to USD	Sales
Cluster 1	-0,848	-0,025	1,458	0,436	-0,388	1,268	0,113
Cluster 2	0,353	-0,196	-0,296	-0,326	0,115	-0,213	-0,324
Cluster 3	0,482	-0,237	-0,524	-0,591	-0,027	-0,395	3,171
Cluster 4	0,157	-0,306	0,398	-0,480	-0,100	-0,393	1,743
Cluster 5	-1,025	1,465	-0,594	1,792	0,040	-0,240	-0,402

Source: self-proceed by the author

Cluster 1: Albania, Bosnia and Herzegovina, Greece, Hungary, North Macedonia, Serbia.

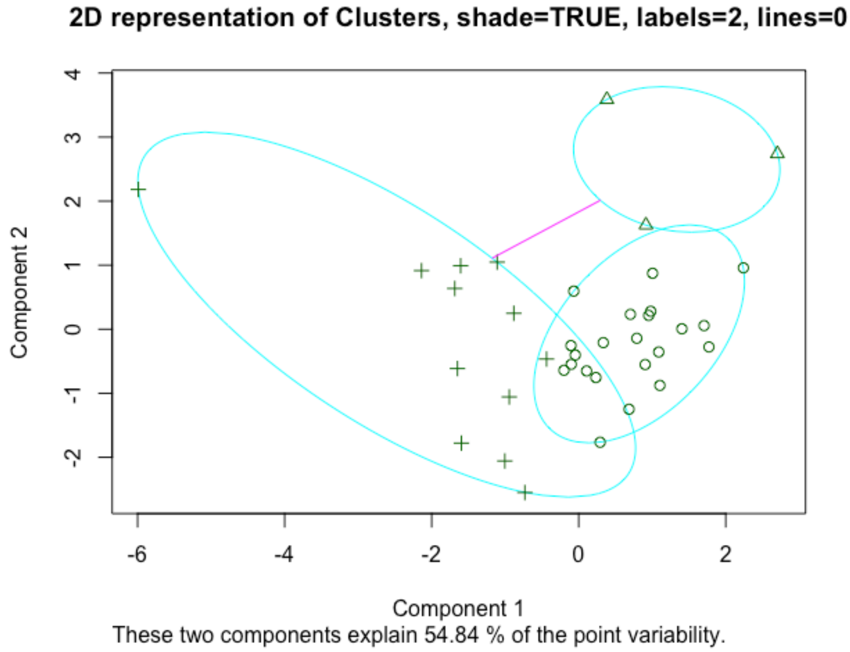
Cluster 2: Austria, Belgium, Cyprus, Czechia, Denmark, Finland, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Sweden, Iceland, Malta, Switzerland, Bulgaria, Croatia.

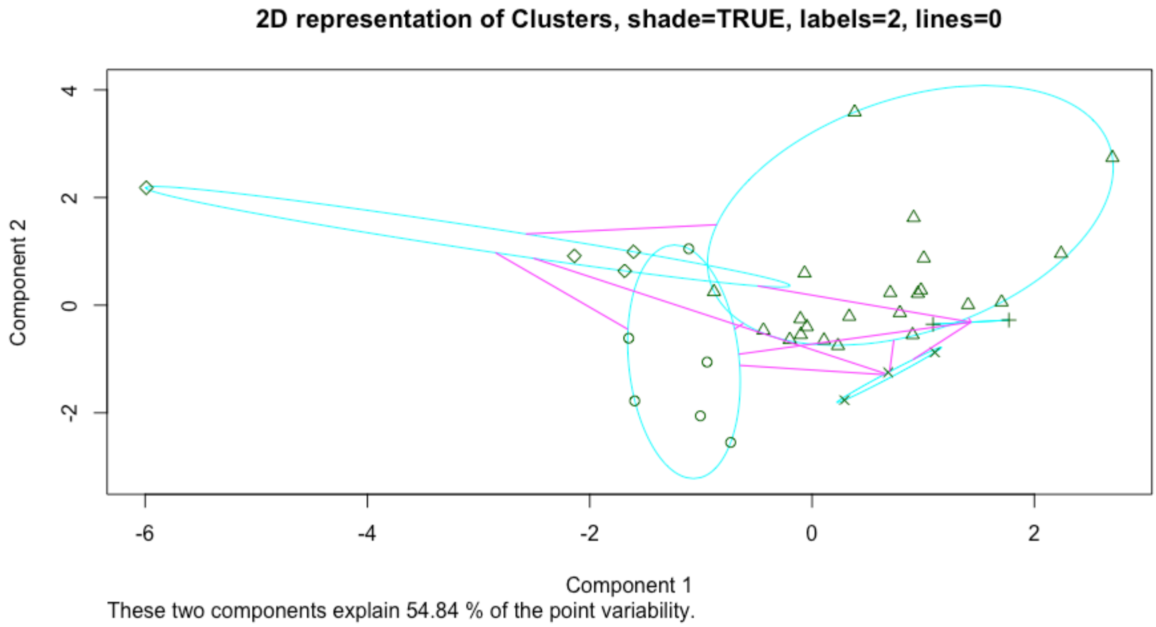
Cluster 3: Germany, UK.

Cluster 4: France, Italy, Spain.

Cluster 5: Belarus, Moldova, Romania, Ukraine.

Appendix 4. Representation of Clusters (k-means, 3 and 5)

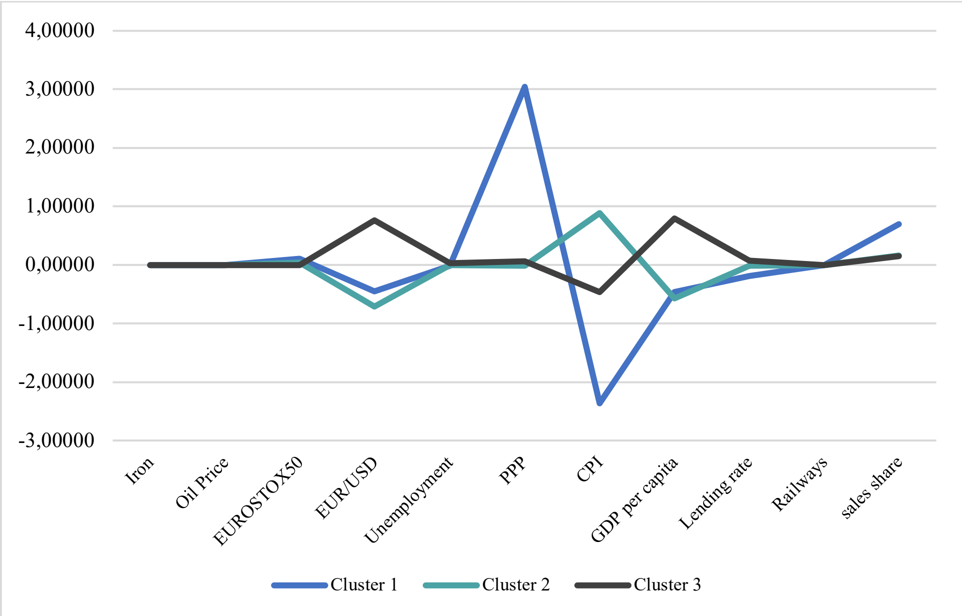




Source: self-proceed by the author

Appendix 5. Means of macroeconomic indicators (k-means, 3)

(rounded to 5 decimal places)



Source: self-proceed by the author

Cluster	Iron	Oil	EUROSTOX50	EUR/USD	Unemployment	PPP	CPI	GDP per capita	Lending rate	Rail lines
1	-0,00017	-0,00039	0,10055	-0,45686	-0,01926	3,04355	-2,36484	-0,46770	-0,18716	0,00001
2	-0,00025	-0,00065	0,04454	-0,71167	-0,00135	-0,01187	0,88613	-0,57502	-0,01889	0,00001
3	-0,00009	0,00051	-0,00339	0,75731	0,02541	0,05831	-0,46432	0,79458	0,06861	-0,00001

Source: self-proceed by the author

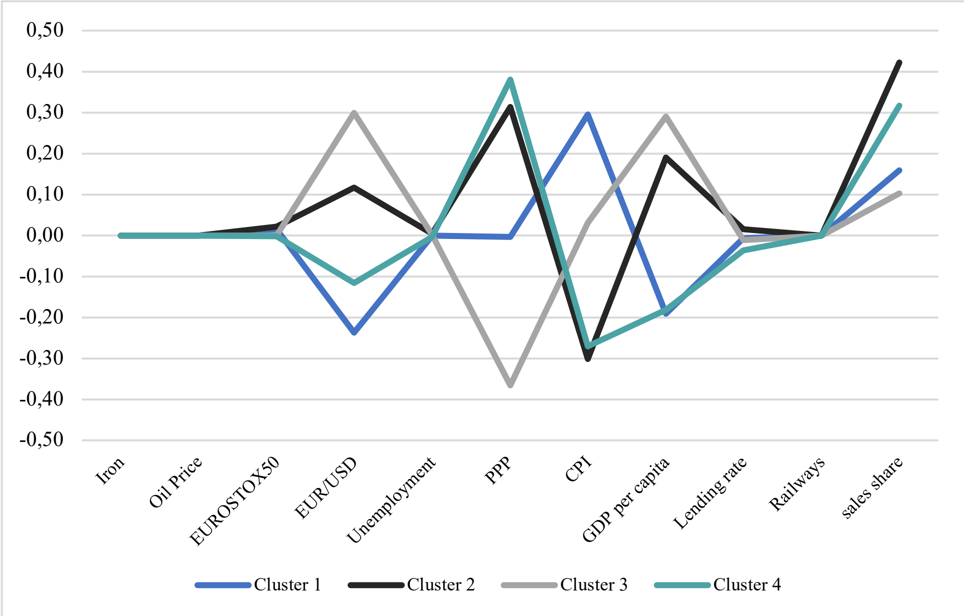
Cluster 1: BMW Group, Daimler AG, Geely Group, General Motors Europe, Group PSA, Hyundai Motor Group, Toyota Motor Corporation and Volkswagen Group.

Cluster 2: Proton / Drb-Hicom, Renault-Nissan Group and Tata Motors.

Cluster 3: FCA Group, Ford Motor Company and Mahindra & Mahindra.

Appendix 6. Means of macroeconomic indicators (k-means, 4)

(rounded to 5 decimal places)



Source: self-proceed by the author

Cluster	Iron	Oil	EUROSTOX50	EUR/USD	Unemployment	PPP	CPI	GDP per capita	Lending rate	Rail lines
1	0,00000	0,00002	-0,00040	0,29910	0,00164	-0,36596	0,03126	0,28960	-0,01202	0,000
2	-0,00018	-0,00023	0,02107	0,11611	0,00497	0,31313	-0,30157	0,18984	0,01487	0,000
3	-0,00008	-0,00022	0,01485	-0,23722	-0,00045	-0,00396	0,29538	-0,19167	-0,00630	0,000
4	0,00012	0,00025	-0,00156	-0,11584	-0,00407	0,38044	-0,27052	-0,18238	-0,03618	0,000

Source: self-proceed by the author

Cluster 1: Ford Motor Company.

Cluster 2: BMW Group, Toyota Motor Corporation, Volkswagen Group, FCA Group, and Mahindra & Mahindra.

Cluster 3: Proton / Drb-Hicom, Renault-Nissan Group and Tata Motors.

Cluster 4: Daimler AG, Geely Group, General Motors Europe, Group PSA and Hyundai Motor Group.