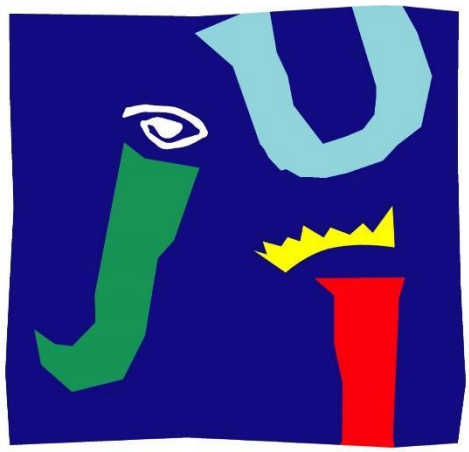

UNIVERSITAT JAUME·I

CONSEQUENCES OF THE IMPACT OF COVID-19 ON THE SPANISH AUTOMOTIVE AND SEMICONDUCTOR INDUSTRIES

Author: Mario Florin Tilichigiu

Tutor: Carla María Martínez Martínez

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1. INTRODUCTION

The objective of the following paper is to understand how the coronavirus crisis has affected the automotive industry and the semiconductor sector, as well as the relationship between the two.

The concepts covered in this investigation are contextualized in the theoretical framework section. Here, we will aim to understand what semiconductors are, and their relevance in today's industry. As well as, the parties involved in the supply chain of this industry. Then the operation of the semiconductor value chain. On the other hand, the information related to the Spanish automotive industry is also stated in this document, getting to understand how the production and the national market works. Also, information regarding materials exports and the supply chain.

Regarding the methodology used in this work, the systematic review of the literature is used. Its objective is the extraction of synthesis based on the available evidence. This study methodology is used to understand the proposed title of this investigation. Based on the compilation of diverse sources of information, conclusions are drawn to help understand the phenomena occurred in the vehicle and semiconductor industry. Mainly specialized sources in the automotive and semiconductor field, such as official private associations, are used throughout this investigation.

This is followed by the question on “how COVID-19 has affected both industries”. Reviewing the impact of the pandemic in the short, medium and long term in the semiconductor sector. As well as the impact on the Spanish automotive sector. Where phenomena such as paralysis of demand, mobility restrictions, bottlenecks (due to excess demand), among others, have occurred. As well as the approach of measures taken for the recovery of the automotive sector.

Finally, conclusions are drawn from the information gathered (through the compilation of various sources) to understand the relationship between the two industries and how they have been affected by the global coronavirus pandemic.

2. THEORETICAL FRAMEWORK

2.1 What are semiconductors?

From an electronic perspective, conductive materials (composite or simple bodies) can be grouped into three main categories: conductors, insulators and semiconductors. Conductive bodies allow the passage of electric current at a low resistance. On the other hand, insulating bodies show a high resistance to the passage of electric current. Finally, the semiconductors, have similar characteristics to the conductive and insulating bodies, where they offer a high or low resistance for the flow of electric current (ANCAP, 2020). Therefore, depending on the given or established physical situation, semiconductors - as raw material - can act as insulators or electrical conductors (OP, 2021).

The variation of resistance to electric current in semiconductors depends mainly on the internal temperature. The higher the internal temperature, the lower the resistance of the semiconductors and therefore the higher the electrical conductivity, and the lower the temperature, the lower the electrical conductivity (ANCAP, 2020).

Regarding its origin in 1940, engineer Russel Ohl discovered that the electrical conductivity of certain crystals varied when exposed to light and alterations in the amount of impurities. Based on this discovery, the first semiconductor was created in 1947 by Jhon Barde and Walter Brattain. Created from the chemical element germanium (Ge), it would serve as the first semiconductor body, becoming a fundamental pillar for the development of current electronics (Alonso, 2020).

Nowadays, semiconductors can be produced from different chemical elements: silicon (Si), selenium (Se) and germanium (Ge). In the modern electronics industry, silicon (Si) semiconductors are mainly used due to their cost competitiveness and easy access, while germanium (Ge) is the least used due to its high price in the market (Alonso, 2020). In addition to these main elements, there are 15 to 20 chemical compounds with similar properties, although these cannot be considered pure semiconductors (OP, 2021).

Today they are a vital component in human life, present in a multitude of electronic devices. Given their insulating or conducting properties, semiconductors are fundamental to the creation of electronic components such as computer processors. Given the binary system

used in computing, semiconductors can be assigned (through charge modification) the value of 0 when they isolate and the value of 1 when they allow electricity to flow, thus being very useful in complex electronic components such as chips and processors (Alonso, 2020).

In short, semiconductors are fundamental in the modern age, their electronic uses are limitless. They are present in all types of electronic devices that people around the world use on a daily basis. It is an element that has brought the digital revolution and technological advances that have improved the quality of the human population.

2.2 Semiconductor industry

The semiconductor industry plays a fundamental role in people's daily lives. From the cell phones we use every day, to the vehicles we use to commute to work, all them carry these tiny parts called semiconductors.

During the last 30 years, the semiconductor industry has grown exponentially and has had a great economic impact. The annual growth rate from 1990 to 2020 is a compound rate of 7.5%, exceeding the world GDP growth equivalent to 5% per year during the same years (Varas, A.; Varadarajan, R.; Godrich, J.; Yinug, F., 2021).

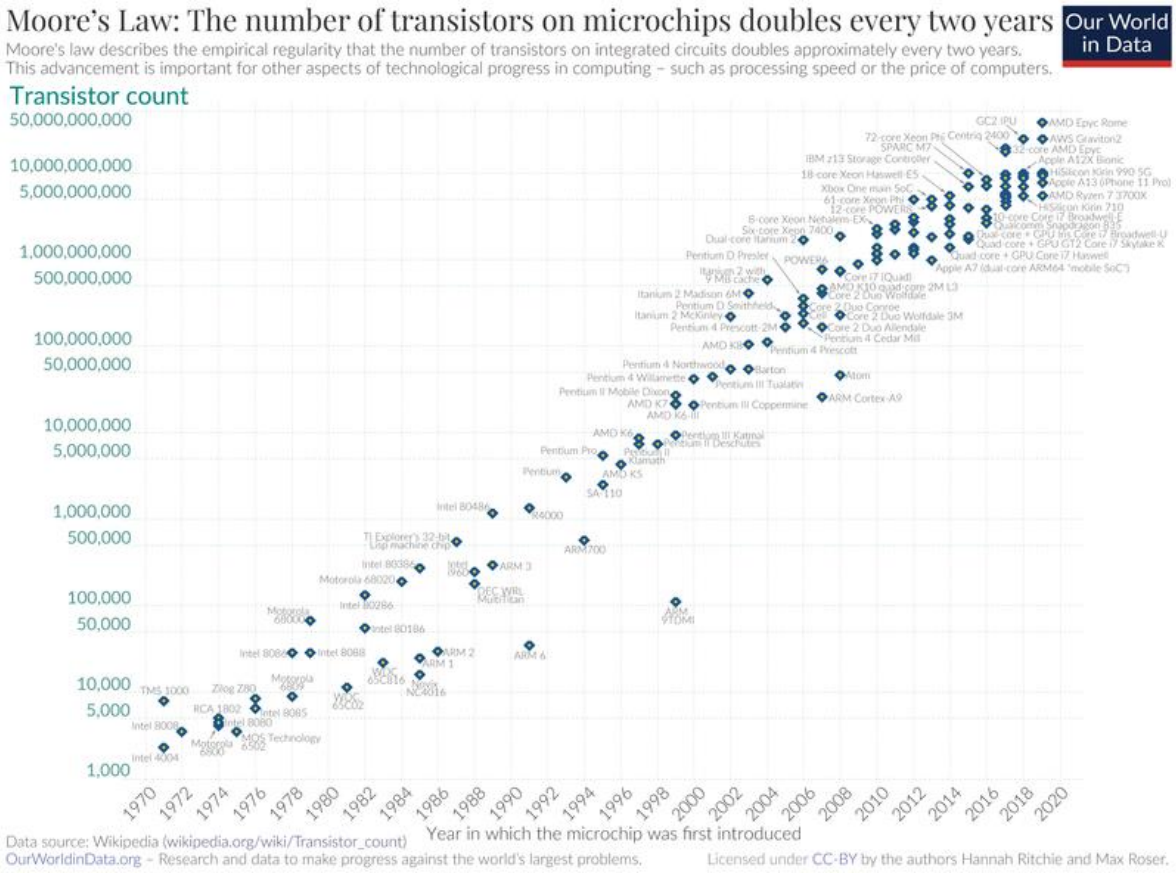
The development and evolution of semiconductors have made possible such important innovations as the computer, online services and smartphones. These innovations have been the engine of global economic growth. The estimate is $3 trillion added to the world economy during the years 1995 and 2015 directly related to semiconductor innovation and development. In addition, it is estimated that there is an increase of $11 trillion coming from the indirect impact of the sector (Varas, A. et al., 2021).

To keep up with the development of new future technologies such as artificial intelligence, 5G technology and electric vehicles will require significant advances in semiconductor technology (Varas, A. et al., 2021). There is a rule of thumb used in the semiconductor industry to forecast the pace of chip development in the short to medium term. Gordon Moore made an observation in 1965 and it was attributed the status of a law. Moore's law is the prediction that the number of transistors on a chip would double every year and at the same time, its cost would drop significantly, but in 1975 he made a correction. What he

predicted would happen in 12 months became 24 months. Since Moore's correction, his prediction has been reasonably accurate (López, J. C., 2021).

Below is a table showing in a more graphic way how Moore's law has been fulfilled from 1970 to 2020, with the number of transistors increasing every two years:

Image 1. Moore's law graphic.



Source: Wikipedia transistor count date 2022

However, it must be taken into account that Moore's law may no longer be valid in the future due to the new trends in technology that are coming in the next 10 or 20 years, such as quantum computing. These new technologies will make current processors obsolete by something completely different and revolutionary (Espeso, P., 2015).

2.2.1. Supply Chain

The supply chain is a global chain as the design and manufacturing of a semiconductor involves most of the following geographical areas: USA, South Korea, Japan, China, Taiwan and Europe (Varas, A. et al., 2021).

Manufacturing a semiconductor requires up to 300 different types of materials, from raw foils to basic and complex chemicals or simply bulk gases. These materials are processed by up to 50 precision and highly specialized engineering equipment (Varas, A. et al., 2021).

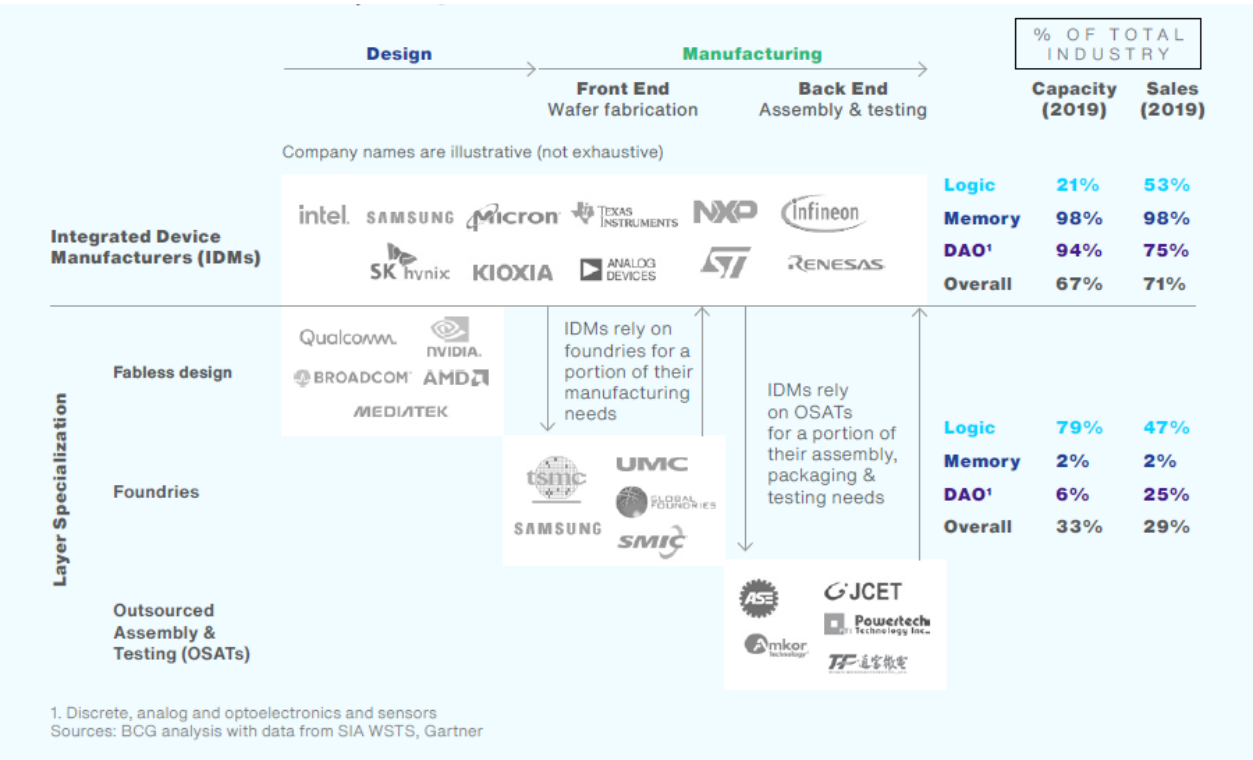
The supply chain of the semiconductor sector is peculiar and sophisticated in several aspects. This chain is made up of different players specialized in each stage of semiconductor creation and production (Iijima Cruz, 2021). The semiconductor industry has up to 30 different categories of semiconductor products and each of these products is designed to be part of a complex electronic subsystem (Varas, A. et al., 2021).

According to Hiromi Iijima in OBELA report number 12 of 2021, there are different types of companies in charge of semiconductor manufacturing and design along the entire supply chain. Up to four different types of companies can be found;

- Integrated Device Manufacturers (IDM): They are responsible for several phases along the entire supply chain. They are responsible for design, manufacturing, assembly and internal testing. Currently, IDM models are common in companies that focus on producing memories and DAOs, i.e., general and scalable components. IDMs account for 70% of global industry sales in 2019.
- Fabless: These are companies that do not have their own factories and are exclusively in charge of semiconductor design. They contract other companies for the production of semiconductors. This model together with the following two mentioned represent almost 30% of global sales in 2019.
- Foundries: they are only in charge of production for third parties.
- Assembly and test subcontractors (OSATs): focus on supporting semiconductor assembly, packaging and testing.

The following image shows the main companies that form part of the above classification:

Image 2. Types of semiconductor companies, depending on their level of integration and business model



Source: Strengthening the global semiconductor supply chain in an environmentally friendly uncertain era. Semiconductor Industry Association (SIA) date 2021

As mentioned above, the suppliers that are part of the industry's supply chain are located around the world. In such a way that there is currently no country in which the value chain is carried out in a complete manner, i.e., all countries where semiconductors are designed and manufactured are interdependent with each other (Iijima Cruz, 2021).

According to the 2021 Semiconductor Industry Association (SIA) there are up to three different criteria for measuring semiconductor demand depending on the points in the semiconductor supply chain:

- Based on the location of the headquarters of customers that manufacture electronic products, such as cell phones, displays, computers, etc. These companies are the main customers of the companies that manufacture semiconductors.

- Depending on where the manufacturing or assembly of the electronic device takes place. In today's markets, devices are commonly assembled in a different country or in several different countries, so that is where the semiconductors must be shipped as they are assembled.
- Based on the location of the end customers who purchase the various electronic devices. Semiconductors are important components of electronic devices, therefore, the demand for semiconductors will be affected by the sales of electronic devices by end users either individuals or companies.

The United States is currently the global leader in the design of electronic devices due to its entrepreneurial strength and because it has the best technical universities in the world and some of the best technology companies. Therefore, these companies in the electronics or automotive sectors are the ones that use up to 35% of the total semiconductors, especially chips for computers and for data centers. U.S. companies including fabless companies and integrated device companies (IDM) account for a combined share of global semiconductor sales of about 50% (Varas, A. et al., 2021).

China and Taiwan are the largest manufacturers of electronic devices. For its part, China has become the country with the highest investment in semiconductor research and patents. Taiwan, on the other hand, invests aggressively in offering incentives for new semiconductor industry, offering reductions of approximately 30% of the total cost of ownership during the first 10 years. Both countries are responsible for up to 60% of the total production of electronic devices such as computers and cell phones. Furthermore, if Japan and South Korea were combined together with China and Taiwan, they would account for approximately 75% of total global semiconductor manufacturing capacity. In addition, they have the advantage that semiconductor companies are in close proximity to the main manufacturing companies of electronic devices and therefore, facilitate the relationship and the global structure of the semiconductor supply chain (Varas, A. et al., 2021).

Europe and Japan are leaders in both, industrial automation equipment and the automotive sector. In addition, South Korea has a large market share in mobile telephony (Varas, A. et al., 2021).

2.2.2. Value Chain

The value chain in the semiconductor industry is as complex, and as globalized as the supply chain. The value chain consists of four important parts, pre-competitive research, IC design, manufacturing and assembly. In addition, the four steps mentioned are supported by a specialized environment formed by suppliers, by the right tools in software design and by complex specialized materials and equipment (Varas, A. et al., 2021).

First of all, pre-competitive research seeks to identify materials and chemical processes that are essential to create new innovations when it comes to architecture, design or manufacturing technology that will enable major leaps in terms of the power and efficiency of technological products. In this first point, governments play a very important role in the advancement of research, since according to a study conducted by the Semiconductor Industry Association (SIA) has identified that 8 of the most important advances in the semiconductor field have been driven thanks to government research programs (Varas, A. et al., 2021).

Secondly, it is the importance of design and patents in the basic architecture of semiconductors. So much so that design accounts for 65% of total R&D within the industry and represents 53% of the value added to the product (Varas, A. et al., 2021). Leading countries such as the USA design processors, radio frequency chips and other specialized chips. Korea, on the other hand, has the leadership in semiconductors used for data storage, where speed and low power consumption are required for processing (Feijoo, C., 2022).

At the same time, the assembly and testing part is largely carried out in Asian countries such as China, Taiwan and South Korea. This stage consists of converting silicon sheets into finished semiconductors ready to be assembled into electronic devices (Varas, A. et al., 2021). Special materials generally extracted from Japan are required for the semiconductors to withstand the power to which they are subjected by the laser machines, to deal with the silicon substrates and also to withstand some of the special gases that are part of the assembly and testing process (Feijoo, C., 2022).

Finally, semiconductor fabrication should be mentioned as the most complex and specialized process of all (Feijoo, C., 2022). It is usually carried out in so-called foundries,

which is where the chip circuits are printed at nanometer scale on silicon sheets. These foundries are mainly concentrated in East Asia, mainly in Taiwan, South Korea, Japan and China. The process requires very specialized manufacturing equipment as very high precision is required at a very small scale (Varas, A. et al., 2021).

A semiconductor manufacturing plant can cost between US$5 billion and US$20 billion, depending on the product to be manufactured. On the other hand, the semiconductor manufacturing process can represent between 30-40% of a company's annual revenues. In short, semiconductor manufacturing accounts for 65% of an industry's total expenditure and 25% of value added (Varas, A. et al., 2021).

According to the study conducted by BCG together with the Semiconductor Industry Association (SIA), if each region wanted to develop its own separate semiconductor manufacturing value chain, the initial investment would amount to approximately one trillion dollars. In addition, at least $100 billion per year is required to keep the entire industry operational. All of this translates into higher costs per chip and thus the cost would be passed on to the final product.

On the other hand, if analyzed from a temporal point of view, achieving the next generation of semiconductors could take between two and five years, taking into account the starting position of the region. If we analyze the case of the European Union in particular, we can see that it starts from an unfavorable position compared to the main regions, which means that the time to reach the next generation of semiconductors would be much longer than in the case of the USA or Asia. However, even if it were possible to reach this generation, the leaders would most likely already be developing much more advanced chips and it would not be feasible to try (Feijoo, C., 2022).

2.3 Automotive industry

The automotive industry is a strategic sector due to its contribution to GDP, currently representing 10% of Spain's GDP and creating jobs for approximately two million people, taking into account the entire value chain. The industry is in a constant process of transformation and is still very much aware of the effects of the pandemic and the economic crisis (ANFAC, 2021).

The current objectives of the automotive industry are to recover the market and keep pace with the transformation of the sector. What is meant by “transformation of the sector”? By transformation of the sector, is understood that the industry aims to decarbonize the fleet by 2050, industrial digitalization and aim for a more circular economic model (Ministry of Industry, Trade and Tourism, 2019). For this, it counts on the EU Next Generation funds that plays a very important role in the recovery of the market and orienting the industry towards a new mobility (ANFAC, 2021).

According to ANFAC's annual report for the year 2021, if the above objectives were met, it would represent an increase in the value of the business of 50%, reaching figures of up to 310,000 million euros. In addition, 1.5 million new jobs could be created and an increase in the GDP of 2 points, representing 12% of the Spanish GDP.

2.3.1 Production and domestic market

Spain currently occupies the second position as vehicle manufacturer in Europe. And holds the eighth position worldwide even though it has suffered a 19.6% drop in production during 2020 compared to the previous year. The drastic drop in production is due to the COVID-19 crisis, which inevitably led to total dealer closures and reduced the activity of production plants between March and May. This situation caused unprecedented drops in production and sales (ANFAC, 2021).

Spain has 17 vehicle production plants belonging to 9 different industrial groups. These factories are spread over 10 Autonomous Communities and there are more than a thousand companies engaged in the manufacture and distribution of components. The production plants are recognized worldwide for their flexible working environment as well as the advantage that the components sector is competitive and diversified. Up to 44 different models are manufactured in these plants. Where 20 of these are world exclusive (Ministry of Industry, Trade and Tourism, 2019).

Despite the reduction in vehicle production, Spanish factories have not stopped innovating in line with the objectives of the sector and have integrated alternative vehicle models into the production chain (conventional hybrids, plug-in hybrids and electric vehicles) reaching a total of 164,821 vehicles produced, representing 7.3% of total production. Of these new models, the most manufactured are the plug-in hybrids with a total of 83,965 units

manufactured which is a significant increase compared to 2019 when only 272 units were manufactured. The new vehicles that follow the plug-in hybrid models are the electric ones with a total of 55,992 units manufactured (ANFAC, 2021).

The table below shows the variations that the main European countries have undergone in terms of vehicle production compared to 2019, thus quantifying the impact on COVID-19 production in the countries of Europe, in this classification Spain is positioned in second place behind Germany:

Table 1. Product variation in European countries in 2019-2020.

Ranking	Country	2019	2020	Variation (%)
1	Germany	4.947.316	3.742.454	- 24,4 %
2	Spain	2.822.632	2.268.185	- 19,6 %
3	Russia	1.720.116	1.435.335	- 16,6 %
4	France	2.175.350	1.316.371	- 39,5 %
5	Turkey	1.461.244	1.297.878	- 11,2 %
6	Czech Republic	1.433.961	1.159.151	- 19,2 %
7	United Kingdom	1.381.405	987.044	- 28,5 %
8	Slovakia	1.107.902	985.000	- 11,1 %
9	Italy	915.291	777.165	- 15,1 %
10	Poland	649.864	451.382	- 30,5 %
11	Romania	490.412	438.107	- 10,7 %
12	Hungary	498.158	406.497	- 18,4 %
13	Uzbekistan	271.113	280.080	3,3 %
14	Belgium	285.797	267.460	- 6,4 %
15	Portugal	345.688	264.236	- 23,6 %
16	Sweden	279.000	249.000	- 10,8 %
17	Slovenia	199.114	141.714	- 28,8 %
18	Netherlands	176.113	127.058	- 27,9 %
19	Austria	179.400	104.544	- 41,7 %
20	Finland	114.785	86.270	- 24,8 %
21	Kazakhstan	49.400	74.831	51,3 %
22	Belarus	30.494	31.273	2,6 %
23	Serbia	35.120	23.375	- 33,4 %
24	Ukraine	7.266	4.952	- 31,8 %
25	Azerbaijan	2.523	1.949	- 22,8 %

Source: Adapted from ANFAC date 2021

The pandemic impacted not only vehicle production, but also severely affected passenger car and SUV registrations. Registrations suffered a 32.4% drop in sales, which translates into 851,211 units registered during 2020. This number implies the largest drop recorded since 2014 (ANFAC, 2021).

In order to reduce the impact on the decline in sales, the Spanish government activated the RENOVE Plan, which consists on offering aid for the purchase of vehicles in order to renew the fleet and encourage the decarbonization of the industry as well as improve air quality. However, the plan was not enough to reduce the impact produced by the pandemic since the incentives were low and it was launched in the last quarter of the year (ANFAC, 2021).

If the Spanish market is analyzed and the registrations by autonomous communities are taken into account, it can be seen that Madrid is the community with the highest volume of vehicle sales with 315,514 units sold, although it is true, that the figure is 31.9% less than in 2019. It is followed in second place by Catalonia with 123,654 vehicles sold, i.e. 28.7% less than the previous year. In third place is Andalusia with 90,055 units sold, which is 32.5% less than in 2019 (ANFAC, 2021).

The following table shows vehicle registrations (passenger cars and SUVs) during 2019 and 2020 and calculates the variation they have undergone during the first year of the health and economic crisis following the closures of dealerships and factories:

Table 2. Variation in registrations by regions in 2019-2020

Ranking	Region	2019	2020	Variation (%)
1	Andalucía	133.388	90.054	- 32,5 %
2	Aragón	24.233	19.117	- 21,1 %
3	Asturias	18.564	12.244	- 34,0 %
4	Baleares	29.999	16.299	- 45,7 %
5	Canarias	58.525	30.105	- 48,6 %
6	Cantabria	10.178	7.868	- 22,7 %
7	Castilla la Mancha	37.755	27.859	- 26,2 %
8	Castilla y León	35.172	26.369	- 25,0 %
9	Cataluña	173.469	123.653	- 28,7 %
10	Ceuta y Melilla	2.438	1.830	- 24,9 %
11	Comunidad Valenciana	130.870	80.346	- 38,6 %
12	Extremadura	14.102	10.206	- 27,6 %
13	Galicia	40.245	30.451	- 24,3 %
14	La Rioja	4.834	3.650	- 24,5 %
15	Madrid	463.308	315.511	- 31,9 %
16	Murcia	29.959	17.005	- 43,2 %
17	Navarra	11.449	8.381	- 26,8 %
18	País Vasco	39.763	30.262	- 23,9 %
19	TOTAL	1.258.251	851.210	- 32,4 %

Source: Adapted from ANFAC date 2021

2.3.2 Export

As can be seen in the ANFAC annual report for 2020, the number of vehicles exported is 1,951,448 vehicles. There has been a decrease in exports of 15.5% compared to the previous year. The main reason for the large drop in exports is due to the closure of markets, factories and the economic crisis, all factors caused by COVID-19. This data is worrying since exports have a very significant weight for the industry due to the fact that 86% of the vehicles are sold abroad, with Europe being the main recipient of total shipments with a 92.7% share.

The main export destinations are France, Germany, Italy and the United Kingdom. The weight of these countries in exports is 64.1% of total vehicles shipped abroad. Thus, if each market is analyzed separately, the drastic drop in demand can be observed. The French market fell by 25.5%; the German market fell by 19.1%; the Italian market contracted by 27.9% and the United Kingdom by 29.4% (ANFAC, 2021).

On the other hand, there are other markets in which demand experienced strong growth in respect to the previous year. It is worth mentioning the Turkish market, which increased purchases of vehicles from Spain by 101.9%, up to 71,791 units. On the other hand, the United States increased its purchases of Spanish vehicles by 2.5% to 24,017 units. If Spanish exports are analyzed on a continental level, America and Africa have suffered falls of up to 16.2% and 24.4% respectively, however, Asia increased its purchases by 3% and the highlight is that Oceania increased its demand by 36.7% (ANFAC, 2021).

The following table shows the 15 main export countries for vehicles manufactured in Spain and their market share in the Spanish market:

Table 3. Main countries of Spanish vehicle exports.

Ranking	Country	2020	Share
1	France	397.641	20,4 %
2	Germany	396.341	19,8 %
3	United Kingdom	241.848	12,4 %
4	Italy	225.748	11,6 %
5	Turkey	71.791	3,7 %
6	Belgium	66.116	3,4 %
7	Netherlands	43.989	2,3 %
8	Poland	42.129	2,2 %
9	Austria	38.259	2.0 %
10	Portugal	36.341	1,9 %
11	Denmark	34.207	1,8 %
12	Switzerland	25.822	1,3 %
13	EE. UU	24.017	1,2 %
14	Sweden	23.504	1,2 %
15	Czech Republic	19.250	1,0 %

Source: Adapted from ANFAC date 2021

2.3.3 Supply Chain

A supply chain such as that of the automotive sector is difficult to specify. The industry is so broad and diversified that each customer-supplier relationship is so complex that it complicates the analysis of this chain (Jiménez, 2006). In Spain, there are important clusters and some technology centers developed in universities with great technological capabilities (García Hermo, 2012).

Vehicle manufacturers perform a variety of tasks, from design, engine manufacturing, vehicle sheet metal fabrication and assembly, body painting to equipment and component assembly. Overall, it is estimated that between 65%-75% of the value of the vehicle comes from component suppliers and equipment manufacturers. The remaining 30%-35% comes from vehicle manufacturers (García Hermo, 2012). Therefore, the choice of suppliers in this sector is vital for the proper development of vehicles.

Currently, an automobile factory designs and produces between 15,000 and 17,000 automobile parts. Other parts, those that cannot be designed and produced by the factory, are supplied by direct suppliers. However, direct suppliers may contract with other sub-

suppliers to procure certain parts. In this way, a chain is created, placing the company in different positions within the chain depending on the type of parts needed and the type of customer (Jiménez, 2006).

The automotive supply chain has a process of interrelation through several stages, also known as links in the chain (Jiménez, 2006). The three elements that are identified and firmly interrelated are:

- The structure of the supply chain
- Structural dimensions
- Members of the supply chain

The structure of the supply chain is known as a network of interconnected companies that are part of a sequence of production and services, from the supply of raw materials to the final construction of the vehicle. In addition, two dimensions are identified, the vertical dimension, i.e. that related to suppliers, and the horizontal dimension, i.e. that related to customers (Jiménez, 2006).

From a vertical dimension perspective, the companies in charge of vehicle assembly are committed to a short supply chain, even asking their suppliers to be located as close as possible to the assembly plants (Jiménez, 2006).

With respect to the horizontal dimension perspective, assembly companies deal with a very small number of suppliers at the highest levels. The intention of this strategy is to place the company in a position of influence within the chain, thus becoming the central company. (Jiménez, 2006).

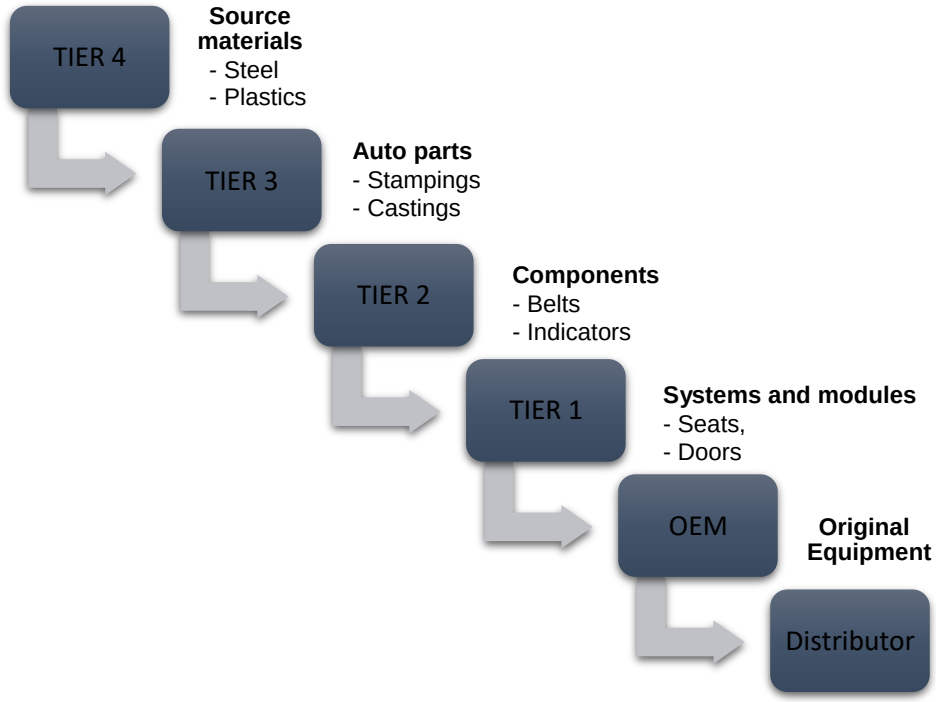
Regarding the identification of members of the automotive supply chain, they can be identified by the functions they perform and their participation in the automotive unification process. In addition, they are classified by the relationship they have with the assembly companies (central companies) (Jiménez, 2006).

When delimiting the automotive supply chain, the starting point is the identification of the central company, i.e., the automobile assembly company. As mentioned above, these central companies are the main link in the chain and are characterized by the fact that they compete in complex markets dominated by very few companies. The suppliers of these companies are structured at very different levels according to their relationship with their customers, the level of technology of the products they supply and the complexity of their production process (Jiménez, 2006).

Once the central company has been identified, the remaining links in the sector's supply chain are analyzed. There are two types of links; the so-called "upstream" links and the so-called "downstream" links. The former are those first-tier (direct) or second- or third-tier (indirect) suppliers that supply the central companies with parts that add less and less value. The second are made up of thousands distributors, commonly known as dealers, whose main function is to sell automobiles to end customers, this being the last link in the chain (Jiménez, 2006).

Figure 1 below shows the general structure of the automotive supply chain and its main components, from raw material suppliers to dealers ready to sell vehicles to end consumers:

Figure 1. Automotive supply chain



Source: Adapted from Jiménez date 2006

The complexity of the automotive supply chain can be observed due to the large number of suppliers in the links away from the main company (OEM). Moreover, the characteristics of each supplier not only depends on how far it is from the main company in the chain, but the global context of each of these suppliers varies according to the location of their factories or the relationship that each one has with their customers. This makes the task of characterizing the automotive supply chain very complicated (Jiménez, 2006).

3. METHODOLOGY AND SOURCE OF DATA

A methodology consisting of a systematic literature review was used for the development of this investigation. According to Manterola et al (2013), it is defined as "the review of quantitative and qualitative aspects of primary studies, with the aim of summarizing the existing information on a particular topic", that is, the elaboration of a synthesis based on the available evidence.

It is an efficient research methodology. It allows a correct evaluation of the results since the information is obtained with great precision, consistency and a high level of generalization. The combination of different studies allows the consistency of the information to be nalyzed. Likewise, the integration of several studies related to the same topic increases the sample size and therefore increases the statistical veracity of the study (Manterola et al, 2013).

In the preparation of this work, various sources specialized in the field of semiconductors and the automotive industry were consulted. The aim is to extract a synthesis based on the information and results from different sources related to the shortage of semiconductors, in order to understand the reason why this phenomenon occurs and to what extent it affects the automotive industry in Spain. Among the sources with the greatest impact on the preparation of this work, the information obtained from the Spanish Association of Automotive Suppliers (SERNAUTO), an organization whose mission is to "represent the interests of the Spanish automotive equipment and components industry", should be highlighted. As well as the Semiconductor Industry Association (SIA), the main semiconductor exporting industry. Also, the Spanish Association of Automobile and Truck Manufacturers (ANFAC), an interest group whose mission is to promote the proper development of the Automotive Sector. On the other hand, the Automotive Sector Report

published in September 2021 by the author Eduardo Irastorza, professor at the EAE Business School in Madrid. Finally, the information extracted from the automotive industry research carried out in July 2021 by the authors Judit Montoriol-Garriga and Sergio Diaz of the CaixaBank Research association.

Based on the information gathered, the relationship between semiconductors and the automotive sector is presented to explain the various factors involved and how they affect this relationship. Likewise, it is stated how COVID-19 has had an impact on the semiconductor and automotive markets, making use of information from various publications. These are focused on the study of the impact that the economy has suffered due to the consequences of SARS-CoV-2.

Finally, conclusions are drawn from the information gathered to show how the Spanish automotive market has been affected by semiconductors. A conclusion based on the synthesis of the evidence developed throughout this work.

4. SEMICONDUCTOR SHORTAGES AND BARRIERS IN THE SPANISH AUTOMOTIVE SECTOR

This section will analyze the dependence of the automotive sector on the semiconductor sector and how the latter has affected the production of automobiles in Spain. The main causes of the global shortage of semiconductors and the bottlenecks resulting from the health crisis will be studied. On the other hand, possible solutions to the problem will be stated, followed by a study of the trends in the Spanish automotive sector.

4.1 Impact of COVID-19 on the semiconductor industry

At the beginning of the year 2020 the whole world had had to face a very serious health crisis due to the global pandemic of COVID-19. The health crisis has affected more than 190 countries at the economic level creating problems and challenges for many business activities and even significant losses for many people. The economic impact of the health crisis has been felt very unevenly around the world, with some countries being hit harder than others. This crisis has managed to highlight all the risks and sensitivities in the value

chain of the semiconductor industry, causing a forced transformation of the global supply chain (Meticulous Market, 2020).

After the first few months of the pandemic, companies in the semiconductor industry began - as in many other industries - to protect employees to try to ensure that the supply chain remains in place, and to take measures to address potential problems resulting from a decline in demand for semiconductors. Major companies in the industry have been forced to rethink their business models to respond effectively to the pandemic. From modifying their product portfolio, to R&D investment strategy, to making decisions involving production and purchasing options from other companies (Bauer, H., et al., 2020).

With no precedent for a global pandemic in modern times, companies live with constant uncertainty. This situation puts them in a difficult position when making important strategic decisions. However, in previous major recessions, it has been shown that companies that addressed strategic decision making early in the crises, were more likely to recover and become market leaders. Based on this, semiconductor companies can focus on the next likely scenarios: the return to normalcy, different trends and long-term demand, and finally how they can emerge stronger from this pandemic (Bauer, H., et al., 2020).

4.1.1 Short-term impact

As mentioned above, it is important for companies to monitor how the market evolves both in the short term and in the long term in order to make appropriate decisions in each of the phases of the recovery of the sector and demand. So the following will detail according to Accenture's 2020 study how the COVID-19 crisis has affected in temporal terms in the three fundamental pillars affected by the healthcare crisis: labor disruption, semiconductor supply disruption and the impact on demand, all in the short and long term:

Demand disruption: The impact of demand disruption and the fact that personnel in many industries have had to move their offices to their homes has resulted in an increase in demand for laptops, desktops, smart electronic devices, etc. This has had a positive impact on the semiconductor industry because the more demand, the more semiconductor

production for all the devices in demand. On the other hand, it has also led to an increase in the demand for cloud services such as data storage, thus increasing the production of external and internal memories.

A closer look at the negative impacts of the demand disruption shows that, due to production stoppages, the automotive sector has been one of the hardest hit. A slowdown has been observed for all automakers and in addition to this, it has affected the sector by negatively varying the demand for vehicles. Vehicle production has slowed down. In addition, consumers due to the confinements suffered and the reduction of mobility have significantly reduced vehicle sales.

On the other hand, if we look at the impact of the disruption of demand in the electronics sector, ranging from mobile telephony to consumer electronics, we can clearly see a negative trend in the loss of revenue due to the confinements carried out around the world, which have caused purchases of mobile telephony and electronic devices to decrease significantly.

Supply interruption: When the supply of semiconductors and raw materials is interrupted due to the health crisis, it is observed that the operations of subcontracted assembly and test companies (OSAT), being the most intensive in terms of personnel required for assembly and testing, are interrupted by travel restrictions in terms of people and/or materials.

On the other hand, the shortage of components and materials required for semiconductor manufacturing leaves the industry and the entire global supply chain in a critical position, creating repercussions and delays in delivery times globally and for all sectors. The supply disruption has created a serious problem in global logistics, creating long delays and increased transportation costs around the world, especially in the maritime sector.

Impact on the workforce: Due to the disruption in production and due to health restrictions imposed by governments, many companies have been forced to adopt remote-work as a way to deal with the barriers imposed by COVID-19. As a result, companies in the

semiconductor and other industries have had to adapt quickly and implement remote-work in a fast and efficient manner.

In view of the increase in remote-work, there is a growing need for flexibility for workers, both on the part of employees towards employers and vice versa. This has created the need for new tools for remote-work, both at software and hardware level, which has also required a period of adaptation on the part of the staff and on the part of the companies.

Due to the increase in remote-work, a period of social distancing was arose in the workplace, causing negative impacts on employees, such as a decrease in their morale or a decrease in the feeling of belonging to the company.

4.1.2 Medium/long term impact

Demand disruption: In the medium/long term, the measures that governments have been taking with expansionary policies in order to stimulate the economy will bear fruit. Consumer spending is expected to increase and, as a result, demand levels will rise to pre-pandemic levels.

On the other hand, remote-work is also expected to remain a new way of working that is here to stay. Remote-work will have positive effects on the demand for cloud infrastructure and storage, which is positive for semiconductor companies.

However, not everything is positive in the medium/long term, the automotive sector will be hardly hit due to the semiconductor sector problem, since a large weight of sales is directed to automobiles. As for vehicle sales, a significant decline is expected through distribution channels and shipments will grow less than expected. This is due to changes in consumer priorities and changes in purchasing patterns following the current uncertainty caused by political, economic and social instability.

Supply disruption: Semiconductor companies have suffered serious problems due to supply chain disruptions. As a result, they have decided to make significant investments in transforming the digital supply chain and enhancing their capabilities.

Another goal of semiconductor companies is to improve agility in the supply network. Creating greater diversification in supply chains with both suppliers and supplier locations. The goal is to eliminate the most fragile points in the supply chain.

On the other hand, companies are betting on the automation of all factories involved in the supply chain. This leads to reducing labor throughout the supply chain and not being so dependent on the human factor in such a globally important sector.

Impact on the labor force: In terms of the labor force, it is expected that workers will increase their productivity due to increased labor flexibility and the ability of companies to organize more elastic positions adapted to new trends. Labor trends focus mainly on remote-working. Employees increasingly value the flexibility that remote-work offers and this leads to greater employee engagement with companies.

4.2 Impact of COVID-19 on the Spanish automotive sector

The first news about the coronavirus began to be heard first in China. They began to analyze the impact that the health crisis could cause in the Asian country in addition to the possible problems of shortages that could even reach European factories due to the lack of parts, raw materials and components. Wuhan, considered ground zero of the COVID-19 health crisis, is the city that accounts for more than 7% of China's electric vehicle production (Cristeto, 2020).

Given the characteristics of the global supply chain discussed earlier in this paper, some producing countries in the automotive industry were considered vulnerable prior to the pandemic. Therefore, large companies began to diversify their supply chains in order to reduce the risks they were facing. However, such complex management is not possible in the short term and diversifying a supply chain is a long-term process (Cristeto, 2020).

If we observe the situation in Spain, the automobile production factories in regards of parts and components, before the arrival of the pandemic, the suppliers located in Spain or in countries close to Spain made weekly or even daily shipments, which caused the stock of

such parts or components to be smaller and with more frequent orders within the factories. However, the parts or components that were ordered from distant countries were ordered in larger quantities in order to have a stock equivalent to two months. This situation allowed the vehicle production factories located in Spain to overcome the first moments of shortage of some parts or components that occurred during the first moments of the pandemic (Cristeto, 2020).

Continuing with the line of analysis of Spanish suppliers, according to the Spanish Association of Automotive Suppliers (SERNAUTO), the components sector for the automotive industry had a turnover of 30.2 billion euros in 2020, which translates into a 15.7% less than the previous year. However, this drop is milder than expected and above all it is much milder than the drop suffered by the vehicle production factories (SERNAUTO, 2020).

On the other hand, in the face of adversity, suppliers have not failed to make significant investments in R&D&I in order to face the new changes in the industrial paradigm that have been sounding since the new environmental regulations that have been promoted by the member countries of the European Union. During 2020, investments of more than 1,070 million euros were made, equivalent to 3.6% of turnover in R&D&I (SERNAUTO, 2020).

Likewise, the components sector seeks to remain competitive and to be able to adapt to the new needs of its customers, and for this reason, during 2020 it did not stop investing to improve its production capacities with the aim of increasing production. The sector allocated up to 1.34 billion euros during 2020. However, this translates into a decrease of 29.6% compared to the previous year (SERNAUTO, 2020).

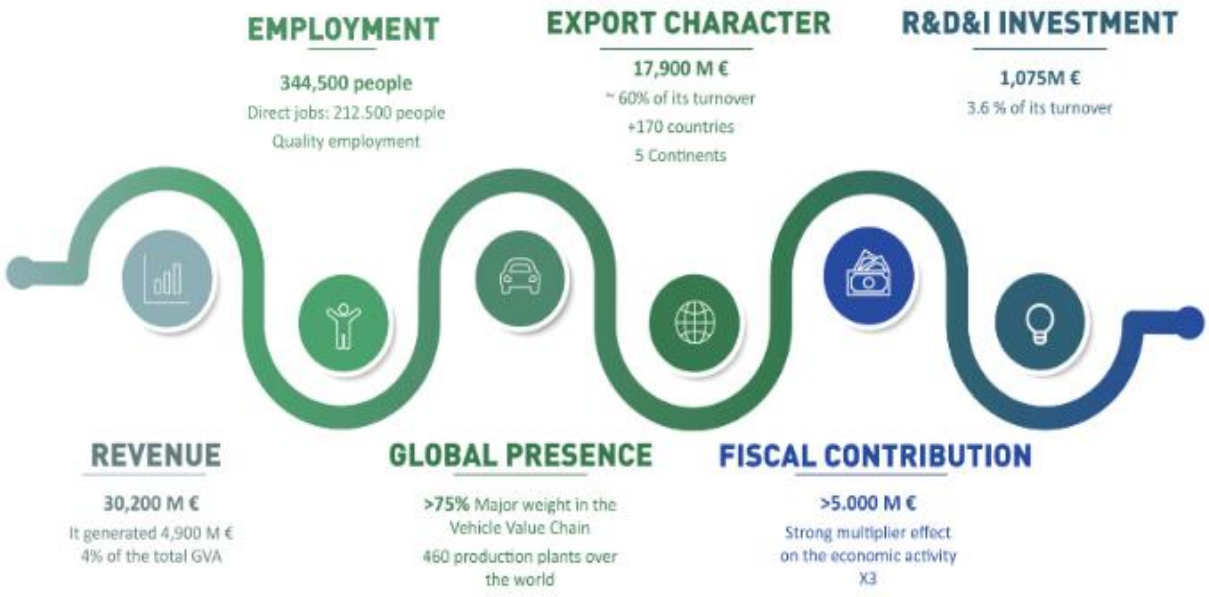
If we analyze the quality of employment in the sector, we can say that it is stable, of high quality and is spread throughout the peninsula. In 2020, the sector employed 344,500 people either directly or indirectly. If direct employment is analyzed, the sector has a total of 212,500 employees. If compared to 2019, this translates into 5.7% less (SERNAUTO, 2020).

In terms of turnover and exports of the components sector, according to an article by the Spanish Association of Automotive Suppliers, some 17.9 billion euros have been exported,

i.e. 13.8% less than in 2019. On the other hand, the national turnover, has suffered a strong contraction of 21% compared to the previous year. Turnover in 2020 in the supply of equipment and components was 7.74 billion.

The following image extracted from the Spanish Association of Automotive Suppliers shows the importance of the vehicle component suppliers sector for the Spanish economy. It analyzes everything from the employment created by this sector to the tax contributions it makes to the Spanish government.

Image 3. Contribution of the Automotive Suppliers to the Spanish Economy.



Source: SERNAUTO date 2020.

The state of alarm that began in mid-March 2020 brought the entire automotive industry to a complete standstill for approximately two months. As a result, the demand for vehicles could not be met during the entire confinement period and economic uncertainty was high. Subsequently, after the reopening of the industry the indicators started to rebound, however, the recovery of the sector at the end of 2020 was not a full recovery (CaixaBank Research, 2021).

If we pay attention to the automotive sector, but this time on the production side, we can see that vehicle production plummeted to 99% year-on-year during April, which is a record for the sector, the lowest ever recorded (CaixaBank Research, 2021). Factories such as Nissan, Renault or Seat had to declare the closure of their plants and carry out the famous Expedientes de Regulación Temporal de Empleo (ERTE) to all employees (Cristeto, 2020).

In the case of the SEAT factories in Martorell, Barcelona and El Prat, 14,812 workers suffered a termination of their employment contract, however, it was decided to apply the ERTE to each and every one of the workers. These factories are where the famous Seat Leon, Ibiza, Arona and Audi A1 models are produced (Cristeto, 2020).

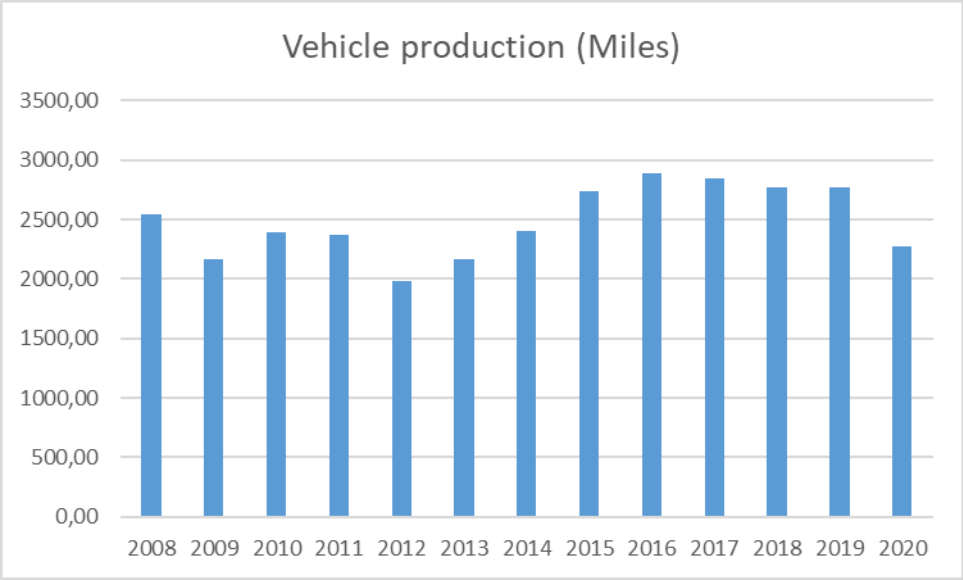
On the other hand, Renault has four factories throughout the peninsula, two in Valladolid, one in Palencia and one in Seville (the latter manufactures vehicle components such as gearboxes). Renault manufactures the Captur, Megane and Renault Kadja models at these plants. During the two months of confinement Renault carried out an ERTE to all its workers, completely paralyzing all its production (Cristeto, 2020).

Nissan, for its part, before the health crisis was already facing a process of permanent closure of its factories or a reduction of the workforce in which up to 600 people would be affected. However, as the factory was operating at 20% of its capacity at the time of facing the confinement, the company had to apply an ERTE to more than 2,400 people (Cristeto, 2020).

Finally, it should be noted that not only these three companies have suffered the serious consequences of the health crisis and the confinement. Spain has plants of many other companies such as PSA with three plants in Madrid and Vigo with more than 14,000 workers. Ford has a production plant in Almussafes which has had to apply an ERTE to more than 7,400 employees. Volkswagen has a factory in Landaben where 4,800 workers have had to stay at home under the ERTES applied by the companies. Mercedes-Benz and Iveco have more than 8,000 employees distributed between the plants in Vitoria and the plants in Madrid and Valladolid. All of them have had to interrupt their production and apply ERTES to 100% of the workforce during the confinement (Cristeto, 2020).

Below, you can see in Figure 2 the production of vehicles during the last 12 years. And you can see the significant decline in the sector during 2020 compared to 2019 due to the pandemic:

Figure 2. Vehicle production



Source: Adapted from ANFAC.

4.2.1 Short-term measures to boost demand

Due to the large number of job losses, the Spanish Chamber of Commerce forecasts that the unemployment rate could exceed 21%, which means a loss of 1.6 million jobs compared to the previous year. This whole situation is causing a clear weakness in demand, which is clearly associated with the increase in unemployment and the increase in savings due to uncertainty. This is why the automotive sector will be one of the sectors most affected by the crisis. The Spanish Chamber of Commerce has proposed a series of measures to face this crisis:

- This is a plan to boost demand. It consists of stimulating the internal demand for vehicles to help with the recovery of the market and boost the renewal of vehicles. This measure will have two positive impacts for the Spanish economy: firstly, fiscal performance and secondly, greater activity in the sector towards different productive branches due to the connection between the automotive and other sectors.

The shock plan supports the purchase of new vehicles either through leasing or via purchase. In addition, it must be complemented with another plan to implement electric recharging infrastructures both in cities and interurban roads in order to cover any type of mobility demand, such as electric motorcycles, for example.

- Fiscal measures to reactivate the market. It consists of eliminating the registration tax and creating a new environmental tax, in this way the vehicle will be taxed according to its CO2 emissions and other pollutants. On the other hand, it is proposed to maintain the current circulation tax, with a 100% bonus for electric vehicles or plug-in hybrids. The latter will improve air quality in cities and will also allow electric vehicles to be taken into account when purchasing a vehicle.

- Another measure is to guarantee ICO resources in the form of a guarantee for the purchase or leasing of industrial vehicles, buses or coaches. As most of the industrial vehicles are acquired with financing, it is intended to offer guarantees to complement the purchase aid plans and thus favor the renewal or expansion of fleets.

4.2.2 Short/medium-term measures to boost supply

After stimulating demand, the next area of action focuses on the relaunching of activity on the supply side. The following measures that have been proposed at the Spanish Chamber focus on the short and medium term with the aim of boosting investment, innovation and Industry 4.0:

- Review of the Strategic Plan for the Comprehensive Support of the Automotive Sector 2019-2025. In this plan, the main objective is to guarantee stability for the investments made within the sector. However, due to the current uncertainty, revisions should be made to update the objectives and commitments that were acquired. Spain's dependence on supplies from third countries should be reduced since, as has been observed throughout this work, the Spanish automotive industry has been paralyzed due to international supply chains.

- Aid for investment within the sector. Plans are proposed to encourage investment in innovation within the automotive industry. Either in the development of products or in the development of processes. To this end, 0% interest loans are proposed, a repayment-free tranche of 15% or 20% or, for example, the admission of pure investment, and no longer just the costs and amortizations.

- Improve the framework of tax deductions for R&D&I investments focused on innovation. It is proposed to broaden the concept of process innovation since Spanish production plants have a strong competitive environment and will therefore be given a competitive advantage if the necessary investments are made.

  It is also proposed to increase access to monetization of investments to more than 3 million euros. Currently, companies that make intensive investments are discriminated against.

  On the other hand, it is requested to approve the freedom of depreciation measures for investments made with the aim of producing electric vehicles as well as components. In addition, the option of eliminating discretion and increasing taxpayer confidence in the application of patents is also being considered.

- It is proposed to promote partnerships between the public and private sectors for innovation and digitization of the sector. The aim is to improve industrial processes, improve energy savings, optimize CO2 emissions in the environment, promote the circular economy and also promote Industry 4.0.

- This will encourage collaboration between different sectors and develop a new value chain that will strengthen and develop the sustainability of the Spanish automotive sector in the long term. By investing in innovation, the clearest competitive advantages of the Spanish automotive sector will be enhanced. In addition, the development of a new mobility, electric, autonomous and connected mobility, must be achieved.

4.3 Impact of the bottleneck on supply chains in the Spanish automotive sector

At the end of 2020, the semiconductor supply chain has suffered a disruption that has severely affected the automotive sector. For the semiconductor supply chain, the pressure is steadily increasing due to the rapid recovery from the constraints experienced during the COVID-19 pandemic. This recovery cycle also coincided with strong demand from the general consumer electronics sector for the year-end holiday season (Fulthorpe, 2021).

It should be noted that the supply chain of semiconductors for systems used in vehicles are typically delivered within 12 to 16 weeks from order to delivery to OEM/TIER 1. Due to the above causes, the automotive industry and vehicle producers have encountered a disruption in the supply of systems composed of semiconductors. The supply disruption has resulted in a doubling of the lead time to approximately 26 weeks or more. It is in this way that bottlenecks have formed that are made up of long waiting lists of orders that are still being shipped and fabs are unable to fill (Fulthorpe, 2021).

A modern vehicle can contain more than 1,400 semiconductor chips. Moreover, these semiconductors play a key role in many of the vehicle's functions, such as engine, steering, locking and unlocking. Shortages of semiconductors have delayed the production of up to 500,000 vehicles globally. Moreover, according to a report by the Spanish Association of Automotive Suppliers (SERNAUTO) in the 17 plants located throughout Spain, 231,679 vehicles were not manufactured between January and May alone due to the lack of these tiny parts (Omedes, 2021).

According to Raúl Morales, communications director of the FACONAUTO dealer association, dealers are currently feeling the impact of this lack of delivery of finished vehicles. Dealers are registering between 20 and 30% less than their target. In other words, if they do not have vehicles to register, they cannot make the necessary sales to meet their sales targets. In addition, there is the problem of vehicle delivery times, with delays of up to 8 or 10 months, which greatly hinders car sales.

However, regarding semiconductor supplies, according to some analysts at IHS Markit, they believe that the chip shortage will come to an end soon. However, it will not be a quick recovery and OEM demand will not be met for the time being. Mid to late 2021 is expected

to see semiconductor production begin and will start to make up for lost demand during the first few months of 2021 (Fulthorpe, 2021).

Another important factor that has aggravated the bottleneck suffered by the sector is the dependence on Europe for semiconductor production and manufacturing. It is estimated that the dependence on Taiwan with TSMC and China with SMIC amounts to 60-70%. In Europe there is currently only one company in the top 50 of semiconductor production, even though the automotive sector in Europe is one of the main semiconductor demanders with a total of 37% of the European demand and 10% of the world demand (Omedes, 2021).

In summary, despite the crisis and the obstacles they have faced during the last fiscal year, vehicle manufacturing companies have closed the year with profits. On the other hand, prices for the end consumer have not been affected because the companies have absorbed the impact of the crisis, thus reducing their profit margins. However, companies recognize that there is still work to be done to achieve the same levels as in 2019 (Omedes, 2021).

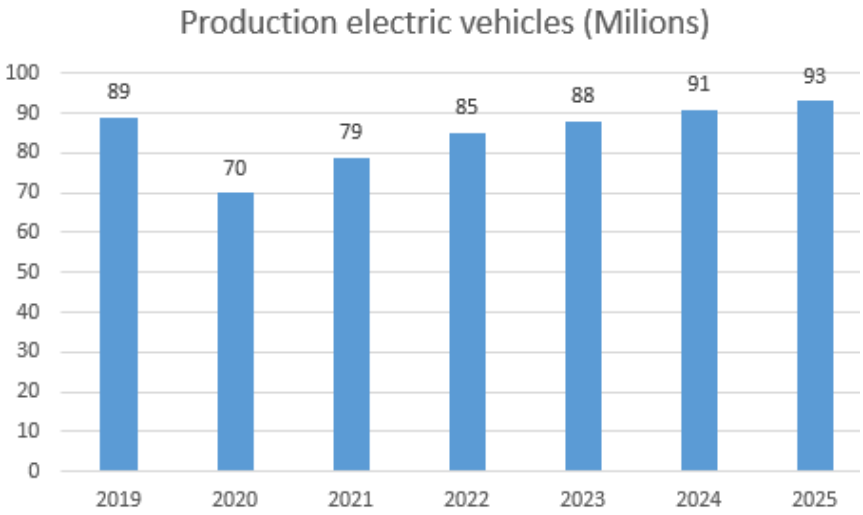
Finally, a possible whiplash effect within the automotive sector must be taken into account. This can occur because companies claim to suffer from a lack of stock and orders are placed in large quantities without really needing that much. Orders are placed with different suppliers and this situation can lead to overstocking, which would cause another major problem to be solved. For this not to happen, it is necessary to keep calm and have an effective communication between production companies and suppliers (Omedes, 2021).

4.4 Trends in the automotive sector

The near future of the automotive sector is undoubtedly electric vehicles. Many governments around the world are aiming for a CO2-free scenario by 2030. To meet the target, important measures have been taken in terms of bonuses for both users and vehicle manufacturers to encourage the transition to sustainable mobility. The sector is at a point of no return, but an orderly transition must be made without damaging the industrial fabric. On the other hand, the renewal of the vehicle fleet is not an easy task when the current world is in crisis or there is a high level of uncertainty regarding the near future (Irastorza, 2021).

Figure 3 shows how vehicle production is increasing year after year, meeting the targets set by governments and the plans to produce 100% electric vehicles:

Figure 3. Production electric vehicles



Source: Adapted from Irastorza date 2021

While it is true that for electric vehicles to surpass current cars, there are still many improvements to be made, such as autonomy, charging time, more charging points, sustainable demand and the recycling of lithium batteries. In addition, it is worth mentioning that most of the costs for the transition to be carried out will be assumed by the vehicle manufacturing companies, which may hinder the transition, making it a complicated task, not at all fast and not at all cheap (Irastorza, 2021).

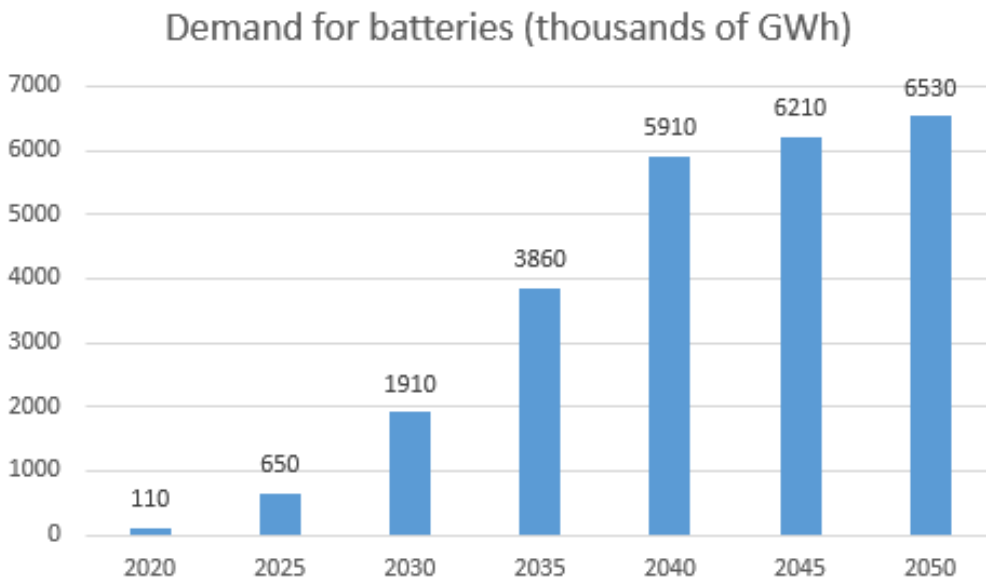
On the other hand, there are still great economic interests in fossil fuels, since they bring great benefits to many countries and governments where oil is the main source of income for the executive. This is why a common and global action is required by all, regardless of borders (Irastorza, 2021).

By 2030, it is expected that there will be more than 100 million electric vehicles around the world. And by 2050, the market share is expected to rise to 70% and electric vehicles are expected to dominate the roads. The market is also estimated to reach over $800 billion in the US (Irastorza, 2021). Companies will emphasize the production of urban vehicles, as the infrastructure for building heavy electric vehicles is not yet sufficient due to the problems

of battery charging and the number of batteries needed to cover long distances and heavy goods (Irastorza, 2021).

Figure 4 below shows how the demand for batteries will continue to increase over the next few years. It can be seen how from 2035 onwards the demand and production of batteries will increase significantly due to the change in motorization by the plans made by governments around the world. Under the objective of reducing CO2 emissions and decreasing combustion engines by that date.

Figure 4. Demand for batteries



Source: Adapted from Irastorza date 2021

On the other hand, it should be noted that it is no longer just a matter of electrifying vehicles, but also of reaching the goal that the car should be as stationary as possible and occupy as little space as possible. To this end, it is necessary to bet on Artificial Intelligence and the collaborative economy (CCOO, 2018).

The automotive sector is still in its infancy when it comes to fully autonomous vehicles. One of the main causes is the lack of connectivity in the sector and for this connectivity to exist, the sector has to face some important legal barriers. Some of the most important Spanish platforms such as Move to Future (M2F) foresee that by the year 2050 there will be a

combination between the concept of vehicle ownership and collaboration between the public and private sector (CCOO, 2018)

As for the Spanish automotive sector, it faces the challenge of modernizing its production structure in order to cope with new technological changes in the field of digitization. Digitalization can provide the sector with a plus to its competitive advantages, productivity and changes in the workplace. Therefore, Spain requires a digital transformation plan to maximize all the synergies between the different sectors (CCOO, 2018).

When talking about digitization, one cannot overlook the fourth industrial revolution, which is based on a data economy, also known as Big Data. The automotive sector has always been at the forefront in terms of innovation in manufacturing processes. In the short term it is estimated that the automotive industry will stop providing products and will move on to providing connectivity services what is also called the internet of things (CCOO, 2018).

In today's automotive supply chain, a substantial change is being observed with regard to components. A current vehicle has approximately 10,000 components, which is equivalent to 70% of its total value, however, of those 10,000 components used for its manufacture 40% corresponds to those dedicated exclusively to vehicle connectivity, i.e. electrical components including semiconductors. It is estimated that by 20 years from now, there will be an increase of up to 80% of these components (CCOO, 2018).

The trend is clear: more and more batteries, more electrical components, more autonomy and more connectivity will be needed. All this points to an increase in the demand for semiconductors and it is expected that globalization and the creation of new semiconductor production plants will be able to supply not only the automotive sector, but also complementary sectors such as telephony and electronics.

5. CONCLUSIONS

Semiconductors are fundamental in today's technology. These elements composed mainly of selenium (Se) are a major component in modern processors and chips. As we have seen, depending on the physical condition, they offer high or low resistance to electric current. Thus, using binary code when they allow electricity to pass through by assigning a value of 1 or when they isolate current by assigning a value of 0. Given this capability of semiconductors, today they are used in all types of electronic devices. Their importance has been of great importance in the digital and computing revolution. They have allowed modern technology to become a reality, enabling technological advances and development.

The technological progress of semiconductors has been constant over time, as evidenced by Moore's law. This states that every 2 years the number of transistors in a microprocessor doubles. However, the projection of semiconductors in the future does not seem clear. Technological advances are becoming more and more disruptive and semiconductors are not expected to have a place in new trends, as is the case with quantum technology. Although it is an element that may be obsolete in the future, today it is still a fundamental and key element in the development of any type of electronic device.

The semiconductor industry is concentrated in certain geographic areas, being mainly: USA, South Korea, Japan, China, Taiwan and Europe. Asian countries account for 75% of the world's total manufacturing capacity, being Japan, South Korea, Taiwan and China. There are also a few companies (Fabless and Integrated Device Companies) in charge of the manufacturing process of these chemical elements, dominating a large share of the market.

The semiconductor assembly process is mainly carried out in China and South Korea. This process consists of preparing semiconductors for incorporation into electronic devices. The manufacturing process, being the most complex (due to its high level of specialization and cost), is mainly carried out in Taiwan, Japan and South Korea.

In terms of demand for these elements, South Korea is the most important country in this respect. It is currently the country that uses the most semiconductors. This is due to the number of electronic devices the country produces. Next, Europe and Japan are the leaders in industrial automation and the automotive sector. They are thus huge demanders of semiconductors due to the demands required by these sectors.

As far as the semiconductor industry is concerned, supply comes from specific geographic areas while consumers are few, but are grouped into large demanders. The production of semiconductors in new regions is unfeasible, since the initial investment requires approximately one billion dollars. It also requires a high level of specialization and know-how that would take time and cost to accumulate. Therefore, the semiconductor industry is currently consolidated in specific regions, and the attempt to move to new areas is unfeasible due to the high economic costs involved.

On the other hand, the automotive industry is a key sector for the Spanish gross domestic product. This industry accounts for 10% of Spain's GDP, in addition to providing approximately two million jobs. This industry is competitive and is in a constant process of evolution. Currently, Spain is the second European country that produces the most vehicles annually, while worldwide it is the eighth country. However, the effects of the coronavirus pandemic have had a negative impact on this industry. Spanish vehicle production in 2020 fell by 19.6% compared to the previous year. This health crisis produced mainly between 2019 and 2020, has led to the closure of dealerships and a drastic decrease in manufacturing. The drop in activity caused a large drop in sales and therefore in production.

Registrations in Spain fell by 32.4% during 2020, the worst figure recorded since 2014. During the same year exports fell by 15.5% compared to the previous year. This last aspect is important since 86% of the vehicles produced in Spain are exported to European countries. While other European countries were similarly affected, France suffered a drop in production in 2020 of 25.5%, Germany by 19.1%, Italy by 27.9% and the United Kingdom by 29.4%. These figures were the result of the impact of the coronavirus, which caused: market closures, sanitary restrictions, lower sales, closure of production plants, problems in the supply chain, among others.

However, despite these conditions, the Spanish industry showed improvements in innovation and technological development. During 2020, new electric and hybrid models were produced, increasing production figures compared to the previous year.

Given these phenomena, the automotive industry suffers consequences from the impact of COVID-19, and the semiconductor industry is also affected. Both the automotive and semiconductor industries did not react in the best possible way to the effects of the pandemic, because there were no precedents from which to draw. There was a great deal of uncertainty that was constant during the health crisis.

First, demand suffered a disruption. This negatively affected the automotive sector by reducing the number of sales. Restrictions were imposed on geographic mobility, which affected the demand for vehicles. On the other hand, the semiconductor sector benefited from these conditions, home confinement triggered demand for electronic products and devices. Sales and demand skyrocketed further causing a bottleneck effect that would negatively affect the automotive industry.

Secondly, the supply chain was affected. Production in the automotive industry came to a standstill and therefore component suppliers had to stop their activity. All parties involved (producers, suppliers, dealers...) in the automotive industry chain suffered a standstill in their activity. This caused a complete standstill for approximately two months. During this time most of the employees in the sector suffered temporary job losses through the administrative mechanism ERTE (Expediente de Regulación Temporal de Empleo). Some companies took drastic actions in this regard, as in the case of Renault, where all of its plant workers ceased their work activity through ERTE (Expediente de Regulación Temporal de Empleo). On the other hand, in the semiconductor industry, the subcontracted assembly and test companies (OSAT) are suffering a stoppage in activity due to the mobility restrictions imposed on the population. These companies are the ones that require more human resources to carry out their activities. As a result of this phenomenon, the semiconductor supply chain is starting to come to a standstill. Delivery delays are created and the semiconductor industry suffers a critical situation, resulting in supply shortages that directly affect the automotive industry.

Third, the labor force is constrained by government-imposed health restrictions. Both the automotive and semiconductor industries suffer a decrease in productivity and economic activity as a result. The adaptation and implementation of telework came at a high cost to these industries. In addition, these industries needed the physical presence of labor as it was essential for production.

And finally, the bottleneck generated by long waiting lists for the acquisition of semiconductors. This phenomenon has arisen as a result of the shutdown of the automotive market. Following the resumption of activity, companies in the automotive industry have ordered large quantities of semiconductor purchases causing a bottleneck effect. Resulting in significant delivery delays, limiting the supply chain and thus slowing down the production chain. It should be noted that Europe is totally dependent on foreign markets for the purchase of semiconductors, and Spain is similarly linked.

Therefore, the automotive industry has been greatly impacted by the effects of the pandemic. Similarly, the semiconductor industry has also been negatively affected by COVID-19, causing an aggregate (unfavorable) impact on the automotive industry.

Based on these consequences, efforts have been made to boost demand and supply in order to favor the recovery of the automotive industry. On the demand side, incentive measures (aimed at the consumer) have been implemented, such as the simplification of leasing purchases, reduction of registration taxes, aid plans, increase in electric recharging infrastructures, among others. Meanwhile, to boost supply, the following have been established: investment aid, tax deductions for investments in R&D&I, freedom of amortization for investments, favoring cooperation with public bodies, reduction of the interest rate on loans, among others.

At present, both markets (automotive and semiconductors) are in the process of recovery. Although, it is estimated that both sectors are far from recovering the figures of normality. However, the sale of electric vehicles is expected to increase considerably, providing an opportunity for both industries to apply technological advances and the development of new innovations. The estimate foresees more than 100 million electric vehicles by 2030. While the market share of electric vehicles by 2050 is estimated to reach 70%. This projection poses a challenge for the automotive industries as they will have to deal with aspects related to electric batteries (charges, quantities, distance, among others).

In short, in today's age, semiconductors are fundamental to human life. As mentioned in this work, a modern vehicle can contain more than 1,400 semiconductor chips. This is an essential element in the automotive industry. The effects of the COVID-19 pandemic have negatively affected the supply of these chemical elements. Thus, directly affecting the vehicle industry. The Spanish automotive industry, one of the most important in terms of GDP, has suffered a historic drop in the number of registrations. In the 17 most important plants in the country, production has been directly affected by the shortage of semiconductors. Despite this crisis, the vehicle companies have absorbed the costs by reducing their profit margins in order not to increase the selling price to the consumer. The semiconductor market is expected to return to normal, where the supply chain functions as usual. While the automotive industry will recover slowly with strong growth in the share of electric vehicles, thus, being the sector most dependent on the use of semiconductors.

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