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Advanced Technologies for Industry – Sectoral Watch

Technological trends in the automotive industry

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Introduction

This sectoral report has been prepared in the framework of the '*Advanced Technologies for Industry*' (ATI) project, initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises.

It analyses trends in the generation and uptake of advanced technologies, related entrepreneurial activities and skills needs in the automotive sector with a specific emphasis on autonomous driving, electric vehicles and related mobility services. It interprets data from a list of data sources compiled to monitor advanced technologies and their applications in industry across Europe and key competitor economies.

The starting point of this analysis has been 16 advanced technologies that are a priority for European industrial policy and that enable process, product and service innovation throughout the economy and hence foster industrial modernisation. Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include advanced materials, advanced manufacturing, artificial intelligence, augmented and virtual reality, big data, blockchain, cloud technologies, connectivity, industrial biotechnology, Internet of Things, micro and nanoelectronics, mobility, nanotechnology, photonics, robotics, security.

The relevance of these specific technologies in the agri-food industry has been explored through patent analysis and data on private equity investments, skills and technology uptake. The full methodology behind the data calculations is available here: https://ati.ec.europa.eu.

This report is structured as the following:

- The first section sets the industrial context.
- The second section analyses technological trends in advanced technologies applied in the automotive industry based on patents and text-mining of company websites.
- The third section presents findings about private equity investment and startup/spinoff activity.
- The fourth section explores the supply and demand of skills related to advanced technologies in the automotive industry.
- The fifth chapter concludes with a short future outlook.

Section 1

1. Setting the scene: industrial context

Key messages

While the traditional automotive industry continues to play an important role in the global economy, it has been facing a number of challenges in recent years: new players enter the market, customers demand new services and the **digital transformation** changes production processes as well as vehicles themselves.

The traditional application areas of vehicles are also changing. The demand for **e-mobility** is on the rise and digital technologies enable new concepts like **car sharing, connected cars and autonomous driving**.

Europe holds a **strong position in exporting vehicles** although relevant parts of the production process have shifted to emerging economies. Value chains are changing rapidly, forcing traditional carmakers and suppliers to adapt their business models.

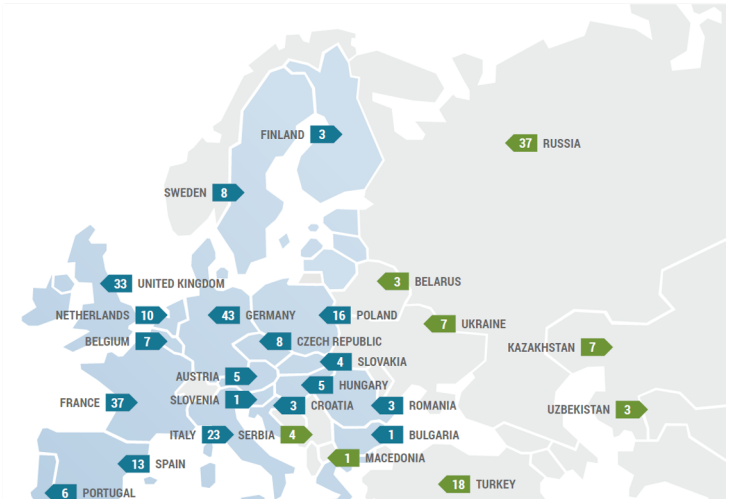
1.1 Automotive value chain: market size and value evolution

The automotive industry has a high impact on Europe's economic growth, development and employment. The industry has been facing a major transformation. Emerging players enter the supply chain, while new technologies and demands are pushing smaller, safer and connected cars, governments set emission standards requiring greener cars and innovations enable the development of driverless cars as well as new mobility services. New technologies change the production process and the overall use of vehicles. New business models and concepts like car sharing create new mobility services. All those changes will also shape the future of the automotive industry as a whole: carmakers as well as suppliers.[1]

The automotive value chain consists of different companies that specialise and produce inputs as first, second or third tier suppliers. The original equipment manufacturer (OEM) defines the design that is used to assemble these inputs into the final vehicle.[2] The automotive production has shifted from early industrial countries (e.g. USA, Japan or Germany), holding the major vehicle brands, to emerging economies.[3]

The European Union continues to hold a strong position in the automotive industry.[4] The leading automotive producer, however, is China with 27.9% of the worldwide motor vehicle production in 2019, followed by the European Union with 21.3%. In contrast, in 2003, Europe still held 33% of the worldwide motor vehicle production while China accounted for a mere 8%. [5] [6]

Figure 1: Number of Automobile assembly and engine production plants in Europe (2018)



Source: European Automobile Manufacturers Association (2019a). The Automobile Industry Pocket Guide 2019/2020.

1 OECD 2016, 5ff.
2 European Automobile Manufacturers' Association 2019a, p. 9.
3 OECD 2016, 4ff.
4 Konstantin Konrad 2018, p. 11.
5 European Automobile Manufacturers' Association 2020c, p. 9.
6 European Automobile Manufacturers' Association 2019b.

Figure 1 visualises the distribution of the 229 automotive assembly and engine production plants in the EU countries[7] (blue) in 2018.

Germany is the worldwide leading automotive exporting country, accounting for 20% (€135.1 bn[8]) of the total world car exports, followed by Japan (12.8%) and the US (6.6%). Spain is the second largest EU27 exporting country of motor cars, accounting for 4.6% of global car exports in 2018.[9] [10] The value of passenger cars exported by EU28 countries (to countries outside the EU) decreased by 3.1% to €128 bn from 2017 to 2018. With a market share of 36.2% in 2018 Asia/Oceania is the EU's biggest export market for motor vehicles, followed by North America with 31.9%.[11] Even though a small group of countries and regions are leading the world automotive production, the automotive value chain has been becoming increasingly complex and global. A growing number of players is involved, operating in different sectors and located in geographically distributed areas. Next to production and assembly, various activities (directly and indirectly linked) are hosted worldwide, e.g. design, testing or research and development (R&D). The traditional value chain which has been developed over time, evolves from vertical integration into a dispersed production network.[12]

1.2 Growth trends in application areas

In 2018 a total of 97.2 m new motor vehicles were registered worldwide, of which 28.5m (a global share of 29.4%) in China. A share of 18.1% (17.6 m) of global new motor vehicles was registered in EU countries in 2018: 15.2 m passenger cars, 2.1m light commercial vehicles (up to 3.5 tonnes), 383,325 commercial vehicles (over 3.5 tonnes) and 41,825 buses/coaches. Within the EU27, Germany, France and Italy recorded the most vehicle registrations in 2018.[13]

The segments of new passenger cars in the EU consist of 35% sport utility vehicles (SUV), 29% small cars, 19% lower medium cars, 8% compact multi-purpose vehicles (MPV), 7% upper medium cars and 3% luxury cars, in 2018. The share of SUV registrations has been increasing since 2008.[14]

The automotive industry shows growth trends in the electrification, automation and sharing of vehicles.[15] While in 2018 the majority of fuel types in new passenger cars registered in the EU represented petrol cars (56.7%), an increase from 5.8% in 2017 to 7.4% in 2018 is visible in alternatively-powered vehicles (with the highest growth in hybrid electric vehicles and electrically-chargeable vehicles). While the use of alternatively powered vehicles rises in the EU, the registration of diesel vehicles has decreased significantly. In 2017, 44% of all new passenger cars were diesel-powered, whereas the share was only 35.9% in 2018.[16] The global electric car fleet exceeded 5.1 m in 2018 representing an increase of 2m from 2017. The biggest electric car market is China, followed by Europe and the US.[17] In 2018 the EU exported electric and hybrid electric cars worth €4.7 bn and imported €1.6 bn.[18] The number of new Battery Electric Vehicles (BEV) in the European market is expected to rise considerably due to new CO2 emission standards set in 2020.[19]

The market for automated vehicles[20] has been booming as well, enabled by the development of digital technologies, such as smart sensors/computer vision, Robotics/Artificial Intelligence (AI) and high-performance computing, connectivity and global positioning/HD maps technologies. On a scale of automation from one to five[21], the levels three (conditional automation) and four (high automation) are currently being tested and are expected to achieve market readiness between 2020 and 2030, whereas levels 1-2 are already on the market. According to various studies, autonomous vehicles will play a crucial role for the EU in seizing the opportunity of creating new jobs and generating profits of up to €620 bn by 2025. In sum, the economic growth of autonomous vehicles is promising and thus will further on play a crucial role in the automotive sector.[22]

Finally, the demand for car-sharing services has increased significantly in recent years. While around five million people used car-sharing services in Europe in 2016, by 2018 the number of users rose to 11.5 m. The European fleet of shared cars almost tripled from 132,000 in 2016 to 370,000 in 2018.[23]

1.3 Automotive employment – a driver of growth and eastward shifts

Broadly defined, i.e. including related services, the EU28 automotive sector employed a workforce of

7 The data include the UK as an EU member state at that time.
8 The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2018.
9 Workman 2020.
10 European Commission 2019e.
11 European Automobile Manufacturers' Association 2019a, 39ff.
12 OECD 2016, p. 15.
13 European Automobile Manufacturers' Association 2019a, 27ff.
14 European Automobile Manufacturers' Association 2019a, p. 35.
15 Frederiksson et al. 2018, p. 1.
16 European Automobile Manufacturers' Association 2019a, p. 36.
17 Till Bunsen et al. 2019, p. 9.
18 European Commission 2019c.
19 Florent Grelier, Julia Poliscanova, Carlos Calvo Ambel, Eoin Bannon and Sofia Alexandridou 2019, p. 9.
20 Automated vehicles have the ability to assist the driver by making use of digital technologies.
21 Level 1-driver assistance, level 2-partial automation, level 3-conditional automation, level 4-high automation and level 5-full automation (European Parliament 2019).
22 European Parliament 2019.
23 ING Economics Department 2018.

almost 13.8 m in 2017 with general services (e.g. sales and maintenance) and transport accounting for the greatest share of employment. The majority of the 2.6 m direct jobs in automotive manufacturing can be found in Germany (869,118), France (223,000) and Poland (202,858), followed by the UK[24] and Romania.[25]

In terms of development, analysing data from 2013 until 2017, the EU automotive sector experienced annual growth in employment. The total automotive employment increased by 1.6% from 2016 to 2017, including 4.1% growth in direct manufacturing employment. However, it is predicted that roughly 10% of direct and indirect manufacturing-related jobs will be cut by 2030 in the EU. It relies on the argument that, on the one hand, the demand for employers in traditional mechanical areas will decrease by roughly 25% due to automation and electrification. On the other hand, a projected 15% increase of the demand for workforce skilled in software and electronics will most likely not cover the caused gap.[26]

24 The data include the UK as an EU member state at that time.
25 European Automobile Manufacturers' Association 2019a, 11ff.
26 McKinsey&Company 2019, 32f.

Section 2

2. Technological trends

Key messages

The analysis of trends in Advanced Manufacturing technology and Mobility patenting reveals a **relatively steady development of the EU27 countries,** while **China is on the rise**. The EU27 countries still hold the largest share of global Advanced Manufacturing technology patents notably 31% in 2017 but the Chinese share grew by ten percentage points from 2007 to 2017[27].

Within the EU, especially **Germany accounts for the largest share of the EU27 patents in Advanced manufacturing** as well as IT for **Mobility**, followed by France. The highest patent growth in the EU27 since 2007 was identified in **IT for Mobility, AI and Security**.

When analysing the adoption of advanced technologies in the automotive industry, the majority of the analysed companies referenced products and services related to the **Internet of Things (IoT), Photonics and Robotics** on their websites. This applies to firms involved in the manufacturing process of vehicles as well as those involved in the use of vehicles and/or related services.

2.1 Technology shifts and advances – emergence of advanced technologies, computing and software technologies

The rapid development of digital technologies is reshaping the automotive industry as a whole on different levels. Table 1 displays three innovation levels affected by technological shifts: vehicle innovations, production innovations and new business models.

Table 1: Overview of technological trends shaping the automotive industry

Innovation level	Technological developments
Vehicle innovations	- Car connectivity - Autonomous driving
Production innovations	- Smart factories - Industry 4.0 applications
New business models	- After-sales services - New car-ownership models - On-demand mobility services

Source: Following Paunov and Planes-Satorra 2019, p. 8

Vehicle innovations describe technological developments in the vehicle itself. Car connectivity is possible through technological enhancements in the collection and processing of data which is then shared and connected to other vehicles. This innovation enables a safer and more convenient mobility as well as new services, such as automated emergency calls in the case of an accident, real-time hazard-warnings, repair diagnostics and optimised route planning.[28] Vehicles are increasingly equipped with systems generating data: installed sensors, brought-in sensors (e.g. through mobile devices) and systems for information and entertainment.[29] According to studies, connected cars are generating up to 25 gigabytes (GB) of data per hour.[30]

Autonomous driving is enabled by fast progress of smart sensors/computer vision, machine learning/Artificial Intelligence/Robotics, global positioning/HD maps and Connectivity. As discussed in chapter 1.2, different levels of automation exist. Currently, many new car models offer assisted driving systems, e.g. vehicle motion control, speed-keeping or assisted parking.[31] The rapid developments in the possibilities of vehicle automation offer promising future prospects. The European automotive industry expects revenues of over €620 bn in the market of connected and automated vehicles by 2025. [32]

Production innovations affect the production process of the automotive industry and are visible in technological developments regarding smart factories and Industry 4.0. Advanced technologies like connected robotics, data analytics or high-performance computing change the manufacturing of vehicles. Among other sectors,

[27] Fraunhofer calculations based on ATI, 2019.
[28] Paunov and Planes-Satorra 2019, p. 8.
[29] European Data Protection Supervisor 2019, p. 1.
[30] Brandt 2017.
[31] Paunov and Planes-Satorra 2019, p. 8.
[32] European Commission 2018, p. 2.

the automotive industry is a leader in adopting smart production innovation.[33] Over 25% of the added value growth in the automotive sector comes from digital innovation, particularly in car design and production.[34] For example, the automotive manufacturer Daimler developed a vision of a smart factory based on technologies like additive manufacturing, machine learning and a production data cloud.[35] Audi and Daimler are using automated guided vehicles for more efficient warehouse transportation and Volkswagen adapts IoT technologies to monitor the shipment of special parts throughout the supply chain.[36]

Innovative new business models will also significantly reshape the general concept of car ownership and mobility in the future. For example, the development of predictive maintenance and automated software updates enable new after-sales services for vehicle owners.

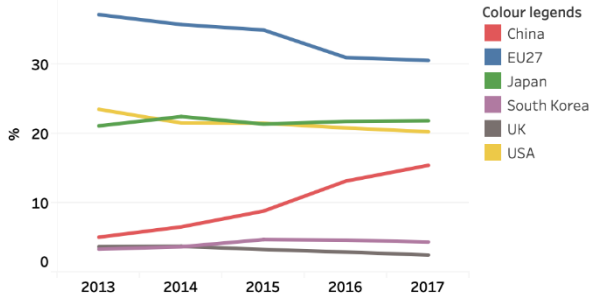
Alternative car-ownership models (e.g. vehicle subscription services) change traditional concepts. Digital platforms and mobile applications offer the basis for on-demand mobility services like car sharing and ride-hailing. [37] According to studies, Europe is the largest and most developed 'Car-as-a-Service' market accounting to 54% of global car leasing.[38] The European market for car sharing is expected to exceed €3.34 bn[39] by 2024 with a predicted compound annual growth rate of over 33% from 2017 to 2024. Some of the key players in the European car sharing market are Share Now, Flinkster, Zipcar and Ubeeqo.[40]

2.2 Trends in patenting of advanced manufacturing technologies and IT for Mobility: large EU27 share while China is on the rise

The patent analysis performed within the ATI project sheds light on technological trends affecting the automotive industry on a global scale. This report analyses patents in Advanced Manufacturing technologies (AMT)[41] as well as IT for Mobility due to their obvious, significant role for technological advances in the automotive industry.

Figure 2 visualises the development of the EU27's and other countries' patent applications in Advanced Manufacturing as global shares between 2013 and 2017.

Figure 2: Share of global patent applications in advanced manufacturing technology (2013-2017)

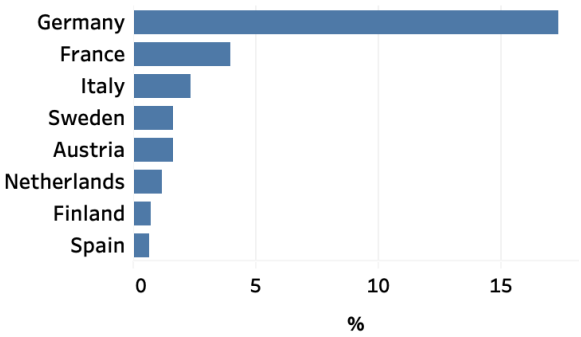


Source: ATI, 2019 Fraunhofer calculations

In 2017, the EU27 countries had the largest share of global patent applications in Advanced Manufacturing at 31%. Nevertheless, its global share has decreased continuously since 2013. While Japan, the USA, South Korea and the UK remain at a relatively stable share of global Advanced Manufacturing technology patents, China is on a rapid rise. While the Chinese share was just above 5% in 2013, it has grown significantly to over 15% until 2017.

Figure 3 zooms into the EU27 Member States with the highest European share of global patents in Advanced Manufacturing in 2017.

Figure 3: EU Member States' share of global patents in advanced manufacturing technology (2017)



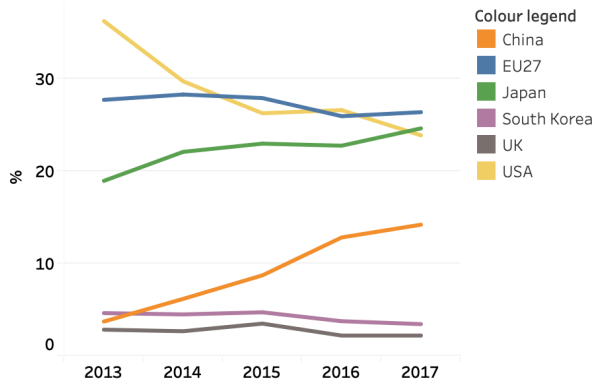
Source: ATI, 2019 Fraunhofer calculations

Within the EU Member States, Germany clearly leads the global share of Advanced Manufacturing technology patents with 17%, followed by France (4%) and Italy (2%).

Figure 4 illustrates the development of the shares of global patent applications in IT for Mobility between 2013 and 2017.

[33] Paunov and Planes-Satorra 2019, p. 8.
[34] European Commission 2017b, 4ff.
[35] Daimler 2020.
[36] Kern and Wolff 2019, 8ff.
[37] Paunov and Planes-Satorra 2019, p. 8.
[38] Roland Berger 2018, p. 4.
[39] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2017.
[40] Graphical Research 2018.
[41] Advanced manufacturing technology encompasses the use of innovative technology to improve products or processes that drive innovation. It covers two types of technologies: process technology that is used to produce any of other advanced technologies, and process technology that is based on robotics, automation technology or computer-integrated manufacturing.

Figure 4: Share of global patents in IT for Mobility (2013-2017)



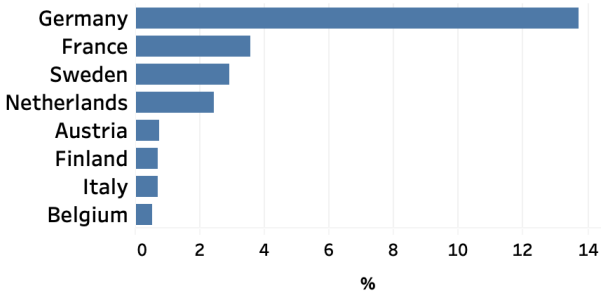
Source: ATI, 2019 Fraunhofer calculations

As visible in Figure 4, China experienced the largest growth of global patent applications in IT for Mobility from 4% in 2013 to 14% in 2017. Japan's share increased from 19% in 2013 to 25% in 2017. In contrast, the USA's position with respect to their global share of patent applications in IT for Mobility declined over time from the highest in 2013 (36%) to the third place in 2017 (24%). The global patent share in IT of the UK and South Korea remained relatively stable within the time analysed.

Another close-up of the EU27 member countries with the highest global share of patents in IT for Mobility in 2017 is given in Figure 5.

Figure 5

Figure 5: EU Member States' share of global patents in IT for mobility (2017)

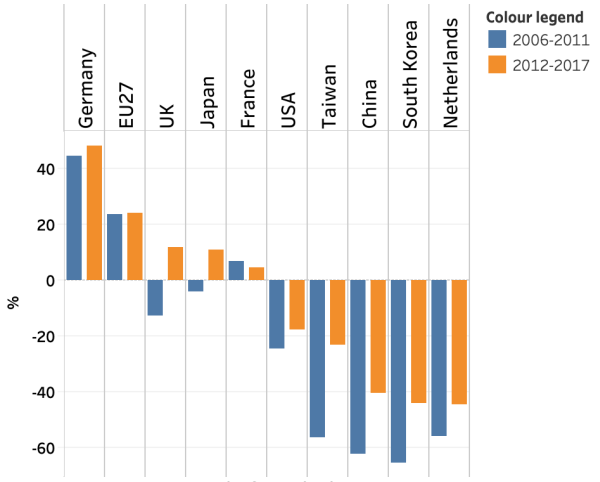


Source: ATI, 2019 Fraunhofer calculations

The graph clearly shows that Germany plays a key role in the EU27 position with contributing to roughly 14% of the global IT for Mobility patents. France, Sweden and the Netherlands follow with 3.56%, 2.9% and 2.4%, respectively.

In the following, the revealed patent advantage index (RPA-index[42]) for Advanced Manufacturing technology and IT for Mobility is analysed in order to measure the relative specialisation of selected countries/regions. Figure 6 visualises the change of the RPA-index in Advanced Manufacturing from 2006 to 2011 and from 2012 to 2017.

Figure 6: Change of the RPA-index in advanced manufacturing technologies (average 2006-2011; 2012-2017) in selected EU countries and competing economies



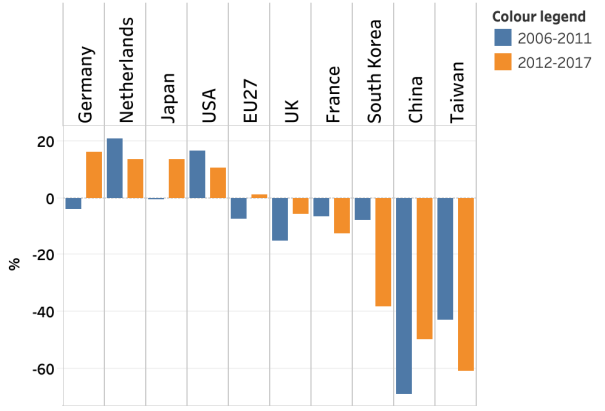
Source: ATI, 2019 Fraunhofer calculations

As visible in Figure 6, Germany set a strong technological focus on Advanced Manufacturing from 2006 to 2011 and even stronger from 2012 to 2017. The EU27-countries, particularly Germany, display an above average specialisation in Advanced Manufacturing. In contrast, the UK, Japan, France and the USA display an about (world) average focus on Advanced Manufacturing and the Netherlands, Taiwan, South Korea and China remain less specialised than other countries in 2012-2017 period.

The next graph (Figure 7) shows the development of the RPA-index for the same countries/regions analysing their specialisation in IT for Mobility. Similarly, to Advanced Manufacturing, Germany also led the specialisation in IT for Mobility from 2012-2017, with a strong increase compared to its specialisation from 2006-2011. The Netherlands, Japan, the USA, UK and France follow with an average specialisation. In contrast, South Korea, China and Taiwan display a rather weak specialisation in IT for Mobility.

[42] The RPA (Revealed Patent Advantage)-index measures the share of an economy's patents in a specific technology relative to the share of total patents owned.
The RPA indices between -100 and -60 indicate an absence of specialisation, whereas values between -60 and -20 points to a weak specialisation, between -20 and +20 to an average specialisation, between +20 and +60 to an above average specialisation and between +60 and +100 to a strong specialisation.

Figure 7: Change of the RPA-index in IT for mobility (average 2006-2011; 2012-2017)

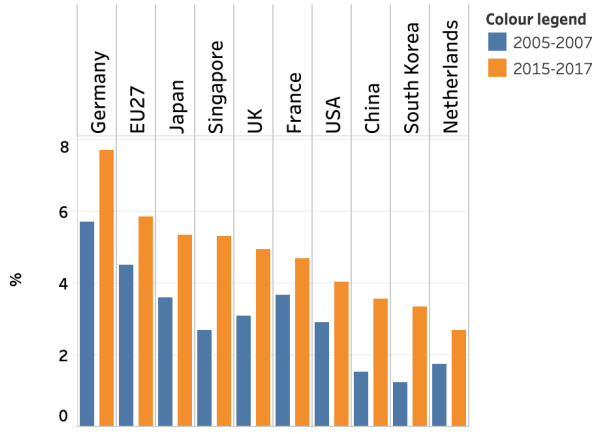


Source: ATI, 2019 Fraunhofer calculations

Figure 8 and Figure 9 point out the shares of patent applications in Advanced Manufacturing technologies and IT for Mobility over the total patent applications at the individual country level in two periods.

As visible in Figure 8, the patents in Advanced Manufacturing technologies as a share of total patent applications grew in all of the countries/regions analysed from 2007 until 2017. In 2017, Germany led with an over 8% share of Advanced Manufacturing technology patents, followed by Japan (5.7%).

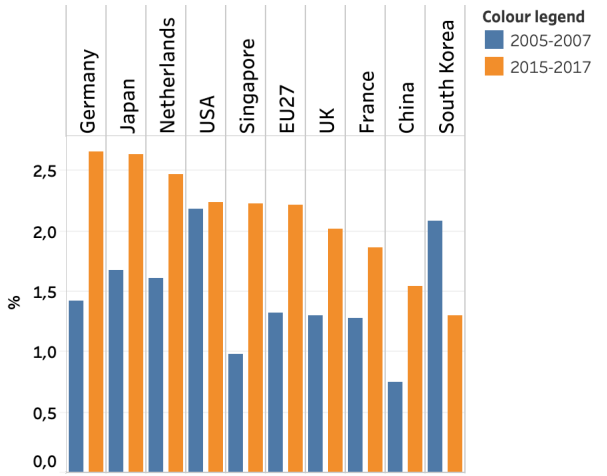
Figure 8: Share of advanced manufacturing technology patent applications over total patent applications in selected countries (2005/7-2015/17)



Source: ATI, 2019 Fraunhofer calculations

When analysing the significance of IT for Mobility as a share of total patent applications (Figure 9) Japan, Germany and Singapore led with relatively similar shares of 3% in 2017. Singapore's share of Mobility patents increased from 0.57% in 2007 to almost 3% in 2017.

Figure 9: Share of IT for Mobility patent applications over total patent applications at country/region-level (2005-2017)



Source: ATI, 2019 Fraunhofer calculations

Overall, all of the countries/regions analysed have a larger share of their total patents in Advanced manufacturing technology than in IT for Mobility.

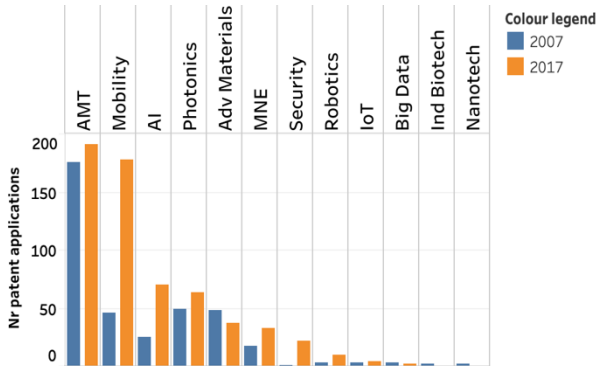
2.3 Technological patenting of automotive firms – advanced manufacturing technology, IT for mobility and AI

In this section, trends in the patent applications filed by the automotive sector is presented with regard to different technologies. In 2017, Advanced Manufacturing, IT for Mobility and Artificial Intelligence were the technology fields with the largest number of patents filed in the EU27 countries. As seen in Figure 10, the highest patent growth in the EU27 countries from 2007 to 2017 is visible in the case of IT for Mobility, AI and Security while the number of patents in Advanced materials decreased until 2017 – despite their significant role for the automotive sector.

While a high number of patents in Advanced Manufacturing and IT for Mobility is closely related to the automotive sector, there is a significant increase in Security related patent applications since 2007. Since the growing internal and external data collection by vehicles enable networking, interfaces and functionalities but also make the vehicles vulnerable to potential cyber-attacks, the demand for security systems protecting the vehicle functions against manipulation increases as well.[43]

[43] VDA 2017, p. 2.

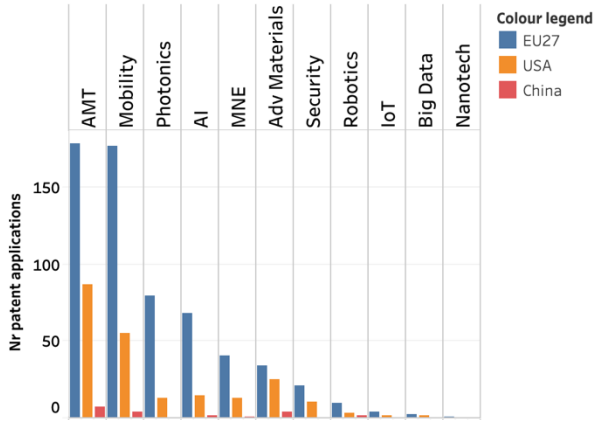
Figure 10: Technology patents by automotive firms in the EU27 in 2007 and 2017 – ranked by the highest number of patent applications in 2017



Source: ATI, 2019 Fraunhofer calculations

Figure 11 displays similar results to the previous analysis, but in an international comparison. In 2017, Advanced Manufacturing technology and IT for Mobility accounted for the highest number of patents in the automotive sector in the EU27 countries, the US and also China. Among those, the EU27 countries led the number of patents in nearly all technologies.

Figure 11: Technology patents by automotive firms – international comparison (2017)



Source: ATI, 2019 Fraunhofer calculations

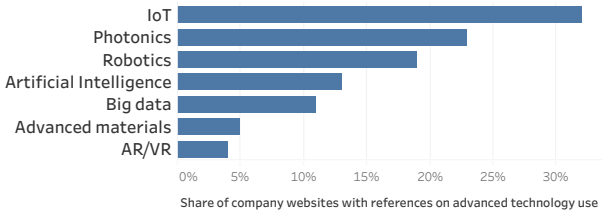
2.4 Technology adoption for enhanced products and services

Advanced technologies can open up new possibilities for manufacturing resulting in enhanced performance, products and services. Thus, they play an important role in the future of automotive companies and create new innovation opportunities. Digital technologies like the IoT, Robotics or Artificial Intelligence are used to make the production process more efficient and intelligent. At the same time, the advanced technologies are also built into the vehicles that are created by automotive manufacturers. For instance, advanced materials, photonics as well as the IoT/Big data are crucial for building smart and connected vehicles.

In order to analyse the technology adoption across automotive companies in the EU, a large-scale text-mining analysis[44] of company websites in the automotive industry was conducted and the results are visualised in Figure 12.

As presented in Figure 12, IoT is the technology appearing most frequently on the automotive firms' websites of the countries analysed, followed by Photonics, Robotics, AI and Big data.

Figure 12: Share of automotive company websites referencing advanced technologies



Source: Technopolis Group based on text-mining company websites

The **Internet of Things** is transforming the automotive industry and creates large amounts of data, which creates new possibilities and challenges. The traditional product orientation shifts to a service- and experience-orientation, software plays an increasingly crucial role and systems are connected and complex. IoT technologies enable this transformation in the production process as well as in the future of vehicles e.g. connected cars. The IoT market in the automotive industry has experienced steady growth over the last years and is projected to grow significantly in the future.[45] Gartner predicts 470 m installed IoT endpoints in the automotive market by 2020. The biggest endpoint electronics revenue is expected to be consumer connected cars with €64 bn[46] in 2020.[47] IoT technologies regarding the smart factory, e.g. connected machines and smart sensors are increasingly used by automotive companies. According to

[44] Based on a search algorithm, company websites were analysed for links to each specific technology. 2,088 websites of automotive firms across seven European countries, including Germany, the Netherlands, France, Austria, Czech Republic, Italy and Spain were analysed. This analysis can reflect about the use of technologies embedded in new products and services and about technological advantages that companies communicate about. It cannot be used however to conclude about the adoption of advanced technologies in terms of the more hidden production processes that are being less revealed in these types of online content.

[45] Krasniqi and Hajrizi 2016, pp. 269–270.

[46] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2019.

[47] Gartner 2019.

Capgemini, smart factories could add up to €142 bn[48] to the global automotive industry through productivity gains by 2023.[49]

Photonics - the science of light - is integrated in various application areas in vehicles for using, creating, detecting and modifying light. Next to basic lighting functions, Photonics technologies provide key features for the advanced driver assistance system: imaging and sensing through cameras inside or outside the vehicle, communication networks and displays. Additionally, Photonics can secure energy supply through photovoltaics in the car. The technology in the vehicle enables safety, comfort and entertainment.[50] As seen in Figure 12, Photonics is the second most present technology referred to by automotive firms' websites in the seven EU countries analysed by text-mining.

The use of **Robotics** in the automotive industry is increasingly demanded in the advanced production process. The rise of automated production drives forward the installation of Robotics. According to the International Federation of Robotics (IFR) the automotive industry was, with 30% (123,439 units), the largest customer industry of global robot installations in 2018.[51]

Automation technologies, such as Robotics and **Artificial Intelligence,** will shape the automotive industry and the nature of its traditional work. AI technologies, e.g. machine learning or deep learning, enable machines to render human-like tasks by combining data, algorithms and computing power [52] AI improves various areas of the vehicle manufacturing process. AI-based algorithms can increase the availability of equipment and thus decrease the risk of unexpected equipment failure. Collaborative robots will work together with humans, increasing the productivity. Moreover, quality can be improved by using AI-based machines which are able to detect defects up to 90% more accurately than humans. Artificial intelligence can improve supply chain forecasts and thus reduce inventory costs by 20-50%. AI driven project management approaches as well as AI-based business support tools increase efficiency and thus reduce overhead.[53] Another area of AI influencing the automotive industry is the integration of AI into autonomous vehicles, which can enable algorithms to use data collected in the car and from sensors in the vehicle's environment to provide the most comfortable and safe ride while adapting to external conditions.[54]

Since the automotive industry has been increasingly digitalising itself, large data volumes from various sources are generated every second. Thus, the demand for data storage, processing and analytics is increasing in order to intelligently process this large amount of data. The cooperation between car makers and software providers becomes critical as technologies like **Big data** and analytics are used to generate and process information from heterogeneous data sources. According to estimations, every automotive manufacturer will collect approximately 11.1 petabyte (PB), which equals 11,100 terabyte (TB), of data in 2020.[55]

The production of vehicles consumes large amounts of construction materials. The requirements on the quality of these materials are high, as they must be long living and reliable in order to meet the customer's needs. This leads to a growing demand for **Advanced materials**. At the same time, the growing competition for materials calls for development of new material types.

The automotive manufacturers increasingly use lightweight constructions as they reduce the structural weight of products. A lightweight vehicle construction enables a longer lifespan of the car and less energy consumption in its use. Innovative materials that enable light weighting, while assuring strength and speed properties of the vehicle, are the key element of the future car design.[56]

The automotive industry uses **Augmented Reality (AR) and Virtual Reality (VR)** technologies both in the production process and in the use of smart/autonomous vehicles. AR technologies can be used for remote inspection and maintenance processes of vehicles. Another example is the use of AR glasses that support workers by displaying complex tasks of the manufacturing processes.

[48] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2019.
[49] Capgemini 2020, p. 13.
[50] European Photonic Industry Consortium 2014, 6ff.
[51] International Federation of Robotics 2019, p. 15.
[52] European Commission 2020, p. 2.
[53] Breunig et al. 2017.
[54] European Commission 2020, p. 16.
[55] Luckow et al. 2015, p. 1201.
[56] Hovorun et al. 2017, 8.

Section 3

3. Venture capital investment and start-up creation

Key messages

In the EU27, Germany has by far the largest activity in VC investment in autonomous/electric vehicles and mobility services, followed by France, Spain, Sweden, the Netherlands and Italy. The largest startup hubs for mobility are located in **Germany, France, Spain and the Netherlands**.

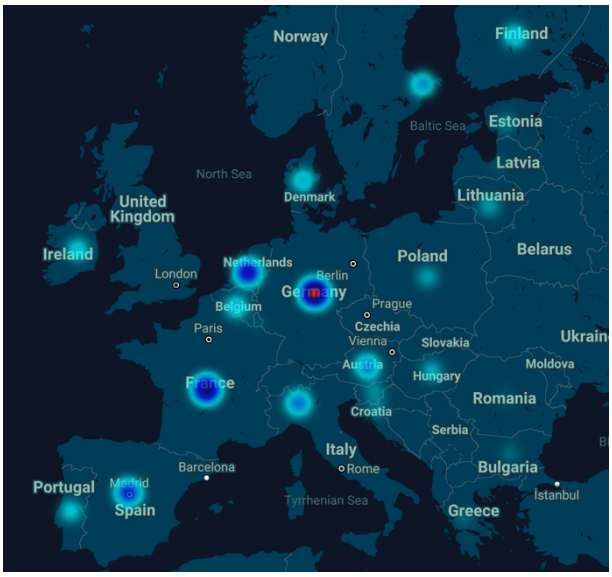
VC and private equity **investment in autonomous vehicles, electric vehicles and related services in the USA and China** were **significantly higher than in the EU27** countries over the last decade.

Startups focus most on automotive related **ICT services and software development**, but logistics, e-commerce and financial and insurance services are also prominent. 8% of the VC-backed automotive startups develop **Artificial Intelligence** enhanced solutions.

3.1 VC and private equity investment in autonomous/electric vehicles and mobility

The scale of venture capital (VC) and private equity investment in the automotive sector varies widely within Europe. Figure 13 visualises the concentration of private investments in autonomous vehicles, electric vehicles and related services[57] in Europe.

Figure 13: Concentration of private investments in autonomous vehicles, 2019

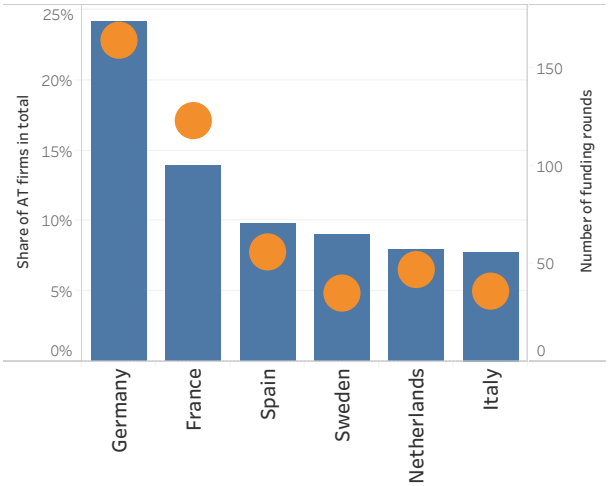


low high

Source: Technopolis analysis based on Crunchbase and Dealroom data using geolytics map

Figure 14 outlines the EU27 countries with the highest number of funding rounds above EU average from 2000 to 2019.

Figure 14: Number of funding rounds and companies in autonomous vehicles, electric vehicles and related services in top ten EU27 countries (2000-2019)



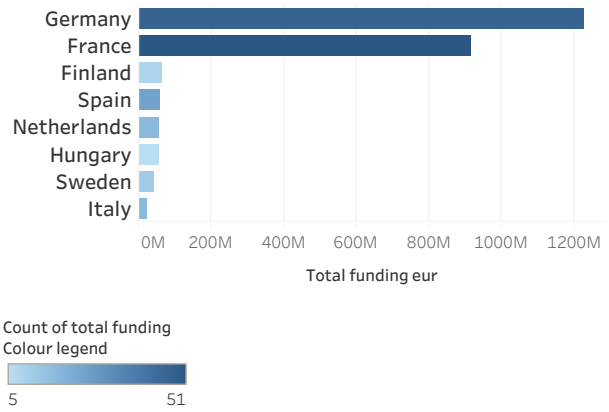
Source: Technopolis Group based on Crunchbase and Dealroom data

As the results indicate, Germany has by far the largest activity in VC investment in Mobility (autonomous vehicles, electric vehicles and related services) in the EU with 164 funding rounds in 113 companies, followed by France and Spain. Sweden, the Netherlands and Italy witnessed also several VC funding rounds in autonomous/electric vehicles including mobility services. Figure 15Figure 18 gives an overview of

[57] Mobility technologies have been defined in this analysis based on the following categories: autonomous vehicles, electric vehicle (Crunchbase), mobility, autonomous vehicles, connected vehicle, autonomous & sensor tech, connected car (Dealroom)

the EU27 countries with the highest above EU average total amount of funding in autonomous vehicles, electric vehicles and related services from 2010 to 2019.

Figure 15: Total amount of last funding in autonomous vehicles, electric vehicles and related services in million € (2010-2019)

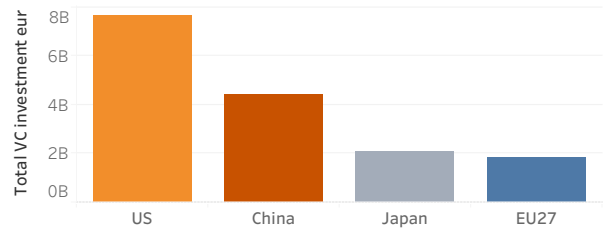


Source: Technopolis Group based on Crunchbase and Dealroom data

Germany has seen by far the largest VC and private equity investment in Mobility with a total amount of €1,225 m from 2000 to 2019. France is the second EU country with the highest investment. Examples of firms that raised high venture capital are Valmet Automotive in Finland, an electric vehicle developer and manufacturer or Canatu that produces 3D shaped touch devices and heater solutions. Sensor heaters will become increasingly important for autonomous driving, as the sensors controlling the driving must be able to operate in any weather. Another example is AImotive from Hungary (with the highest deal value at national level) that is a global solution provider of AI powered self-driving technology.

Venture capital investments in Mobility have been increasing gradually in the EU27 since 2010, nevertheless VC funds invest more in the US and China, as shown in Figure 16.

Figure 16: Total last funding amount (2010-2019) in international comparison, in eur

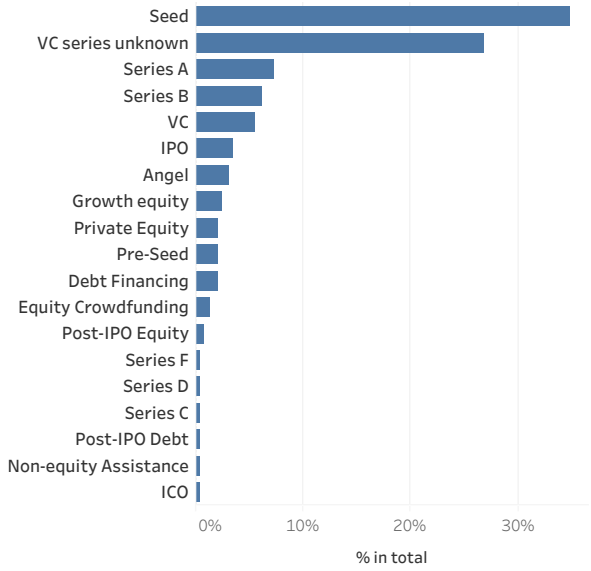


Source: Technopolis Group based on Crunchbase and Dealroom data

The highest amount of venture capital funding in the area of autonomous vehicles, electric vehicles and related services could be identified in the US. In line with this, the largest number of funding rounds were also carried out in the US during that period. The Chinese venture capital investments in Mobility were also higher than in the EU27. Nevertheless, relatively many funding rounds were carried out in the EU27 countries compared to the comparatively lower level of Mobility VC investments.

Figure 17 shows the prominence of different funding types in Mobility in the EU27 countries from 2010 until 2019. The largest number of funding has been seed capital, followed by VC and Series A funding.

Figure 17: Type of funding in the automotive sector (2010 - 2019)



Source: Technopolis Group based on Crunchbase and Dealroom data

Notes: IPO refers to Initial Public Offerings, ICO –Initial Coin Offerings

While the more traditional foreign investors are present in all sectors of the EU27 economy, new investors tend to focus on acquisitions in specific sectors, such as the automotive industry, IT or aeronautics.[58] The sector of automotive equipment and parts received the second highest share of Chinese state-owned capital by value from 2000 until 2018.[59]

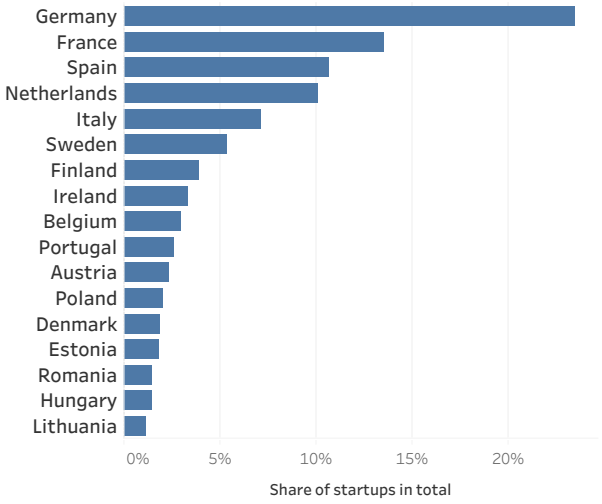
3.2 Automotive startups[60]: focus on software, financial services, Apps and AI

With the aim of exploring entrepreneurship trends in the European automotive industry, the number

[58] European Commission 2019b, p. 67.
[59] European Commission 2019b, p. 60.
[60] This analysis defines startups as established after 2009.

of startups from 2009 until 2019 was analysed based on Crunchbase and Dealroom data. The country distribution of startups is visualised in Figure 18. According to this analysis, the largest VC-backed startup hubs for automotive are located in Germany, France, Spain and the Netherlands.

Figure 18: Startup creation in the automotive industry in the EU27 (2009-2019)



Source: Technopolis analysis based on Crunchbase and Dealroom data

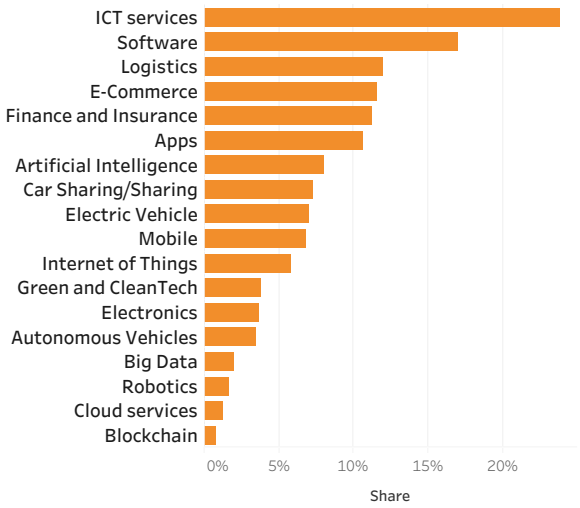
Beyond transportation solutions and manufacturing of automotive parts, startups focus most on automotive related **ICT services and software development**. For instance, the Austrian ESS Engineering Software Steyr develops specialised fluid simulation, 3D-data software for the automotive industry. The German Ekoio is an intelligent driving assistant to promote ecological-economic driving with a reward system. Logistics, e-commerce and financial and insurance services are also prominent.

Artificial Intelligence including machine learning and computer vision is a topic of 8% of the automotive startups in the EU27. Examples include the French Altaroad that offers a real-time analysis of data allowing to measure the footprint and the weight of vehicles. The Portuguese Stratio offers automotive engineering services by leveraging machine learning with the objective of automating anomaly and fault detection.

Car sharing services and sharing platforms are also common among startups. The French Drivy (recently renamed Getaround) is a car rental marketplace in Europe. The service allows its users to rent people's cars everywhere within walking distance of home whenever they need one.

Electric vehicles and autonomous vehicles are in the focus of 6% and 3% of the startups respectively. The most are headquartered in Germany and France such as the German Comodule which is a universal data monitoring and visualisation platform for light electric vehicles. The application allows the user to make routings while sending usage data to original equipment manufacturers (OEM). The OEM can collect data for better development decision and has direct marketing access to all users.

Figure 19: Type of related fields of automotive startups (2009-2019)



Source: Technopolis analysis based on Crunchbase

Greentech, cleantech and sustainability solutions are being developed by only 3% of the automotive startups.

Internet of Things, despite its high relevance for the industry, is also a less common activity for startups. On the one hand, IoT is a more specific activity for startups than for instance, ICT services which are simpler to venture into. Nevertheless, IoT is also a technology field in which only a fairly big company would have sufficient diversity of knowledge and production capacity to develop viable and relevant original designs.

Section 4

4. Skills supply and demand

Key messages

The **highest share** of professionals skilled in advanced technologies and employed in the automotive sector was related to **Advanced Manufacturing**, followed by IoT, AI and IT for Mobility. Compared to the US, **a higher share of professionals in the automotive industry possesses advanced technology skills in the EU**.

The EU27's leading countries supplying technological **experts in Advanced Manufacturing** in the automotive sector are **Germany, Italy, France and Sweden**.

The industry is increasingly building up a **workforce specialised in Mobility technologies**. As digitalisation thrives, the **demand for a workforce skilled in data management** increases, as seen in high growth rates in Big data, Blockchain and Security.

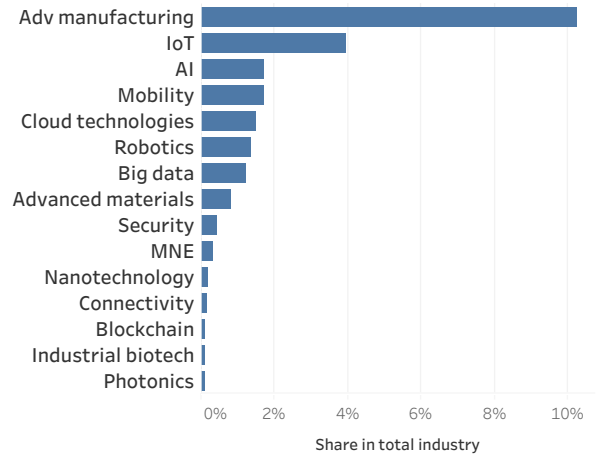
Technological **skills in IT for Mobility and Big data** show the highest growth rate across all EU countries in the automotive sector in the period from 2018-2019. Skills that have been most in demand by automotive firms include: Security, Robotics, Mobility, IoT, Cloud and Advanced materials.

4.1 Availability of new technological skills -prominence of advanced manufacturing

As discussed in the previous sections, the traditional automotive industry is going through a transformation and therefore firms must work hard to achieve and maintain global competitiveness. Among the main prerequisites for success are the skills and the competences of employees, adapted to changes in production, business models, and even in the needs of customers. The application and further development of technologies by skilled employees will influence the future of a transformed automotive industry. Figure 20 visualises the current number of professionals specifying in the top seven selected technological skills in the automotive industry in 2019. This analysis is based on LinkedIn[61] data.

It indicates that Advanced Manufacturing related skills have the highest share among professionals employed in the automotive industry (10% of employees), when comparing the advanced technologies within the focus of this report. The next most popular skill is IoT followed by AI, IT for Mobility[62] and Cloud technologies. All of the most prominent skills can be closely linked to advanced production processes as well as connected and autonomous driving.

Figure 20: Professionals with technological skills in the automotive industry as a share of total industry professionals (2019)



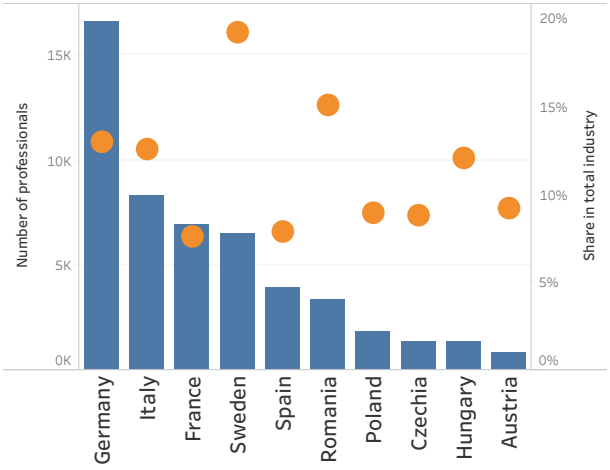
Source: Technopolis Group based on LinkedIn analysis

While Figure 20 illustrates the general distribution of technological skills in automotive across all EU countries, Figure 21 depicts the geographical distribution of the most represented skills in Advanced Manufacturing across the leading ten EU countries with Germany, Italy, France and Sweden at the top.

[61] To harvest the data from LinkedIn, keywords capturing skills by advanced technology have been defined and reviewed by technology experts. Queries have subsequently been constructed to filter the database by location and industry.

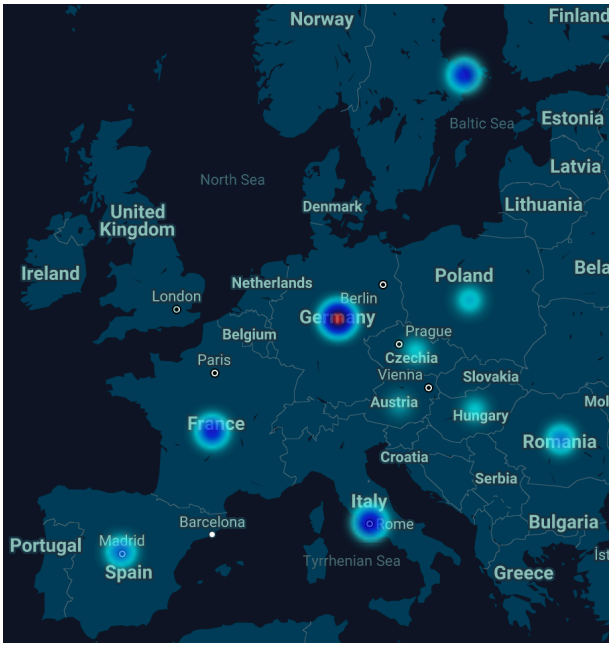
[62] In the LinkedIn analysis IT for Mobility has been defined as including autonomous driving, internet of vehicles, electric vehicles, intelligent transportation and navigation.

Figure 21: Professionals with skills in advanced manufacturing employed in the automotive industry among top ten EU countries (2019)



Source: Technopolis Group analysis based on LinkedIn

Figure 22: Concentration of professionals with advanced manufacturing skills in the automotive industry above EU27 average (2019)

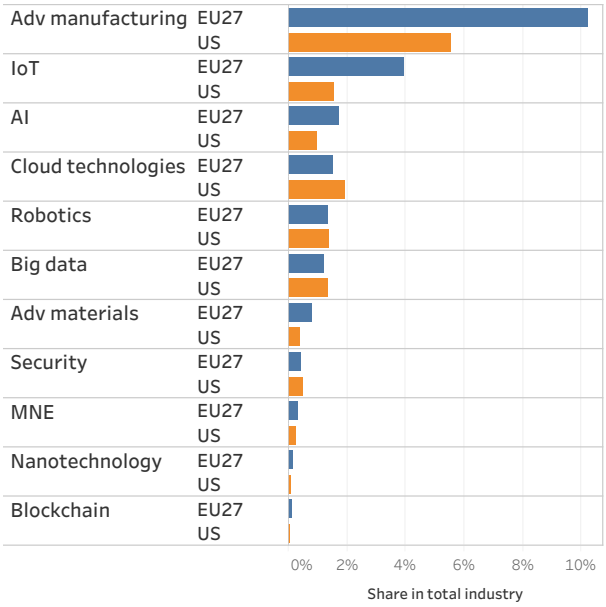


Source: Technopolis Group based on LinkedIn analysis, geolytics map

In absolute terms it is Germany leading the list of skilled professionals in Advanced Manufacturing employed in the automotive industry, followed by Italy, France and Sweden. When looking at the relative share of professionals in the total national automotive industry as registered on LinkedIn, we observe a high share also in Romania and Hungary. These figures need to be interpreted, however, in the light of the representativeness of LinkedIn data compared to the actual employment in the automotive industry. Figure 22 visualises the concentration of EU's Advanced Manufacturing professionals on a map.

When comparing the automotive industry professionals' skills profile in the EU27 and the US, it is found that the **EU27 has a higher share** of professionals employed in the automotive industry especially in the fields of **Advanced Manufacturing and IoT, but also Advanced materials, AI and Nanotechnology than the US**. Where the automotive industry employs less professionals than in the US is Big data, Cloud technology and Security.

Figure 23: Share of professionals with skills in advanced technologies in automotive in the EU27 and US (2019)



Source: Technopolis Group analysis based on LinkedIn

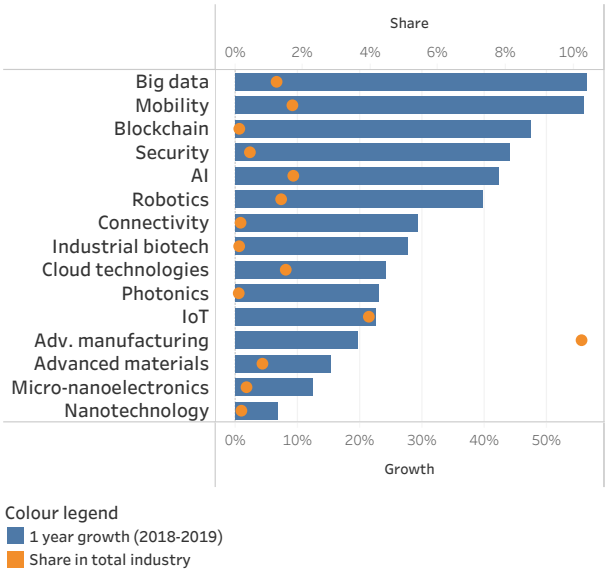
4.2 Demand for new skills: big data and autonomous driving

After analysing the availability of technological skills in the automotive industry, it is also important to estimate potentially highly demanded skills in the future. Thus, the one-year growth rate of technological skills is being analysed by comparing skills indicated in 2018 and its change to 2019.

Figure 24 visualises the technological skills ranking them in terms of the biggest annual growth but also displaying the absolute shares. Beyond Advanced Manufacturing and IoT (as seen in section 4.1), other skills showed significant

growth in demand for the automotive industry, notably Big Data and Mobility.

Figure 24: One-year growth (2018-2019) of advanced technology skills and share in total industry

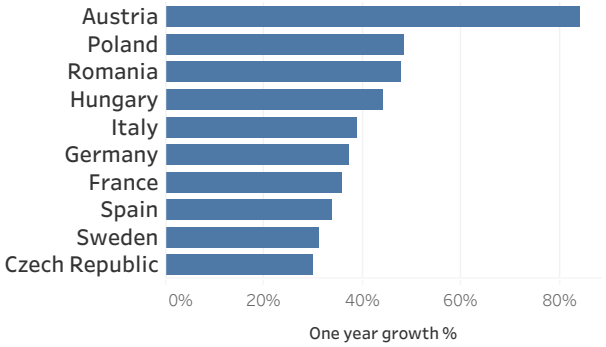


Source: Technopolis Group based on LinkedIn analysis

Skills in Big data and Mobility experienced the largest growth rate of 56% and 55% respectively from 2018 to 2019. Also, the skills in Blockchain and Security display a strong increase of over 40% within one year. Thus, it can be concluded that the automotive industry is increasingly looking for a workforce that is skilled in general mobility technologies. The adaption of new mobility concepts is transforming the car industry and must therefore be understood by its employees. Moreover, as digitalisation thrives, the demand for a workforce skilled in data management increases, as seen in high growth rates in Big data, Blockchain and Security skills. Similarly, automotive firms in Europe require expertise in handling new technologies such as AR/VR with the aim of effectively managing process and product transformations. The demand for highly qualified specialists in these technologies is also driven by the increasing development of autonomous vehicles in the automotive industry, which requires the cooperation of experts from various fields.

The next figure gives a closer geographical perspective into the EU27 countries with regard to the highest growth in the number of professionals with skills in digital technologies in the automotive sector specifically. Figure 25 displays the top EU countries ranked in terms of highest growth. The analysis indicates that it is Austria, Poland, Romania and Hungary where the number of professionals indicating digital skills increased the most. Within this ranking one has to keep in mind that the total number of professionals in the automotive industry is lower that for instance in Germany or France, hence it is easier to reach a higher growth rate.

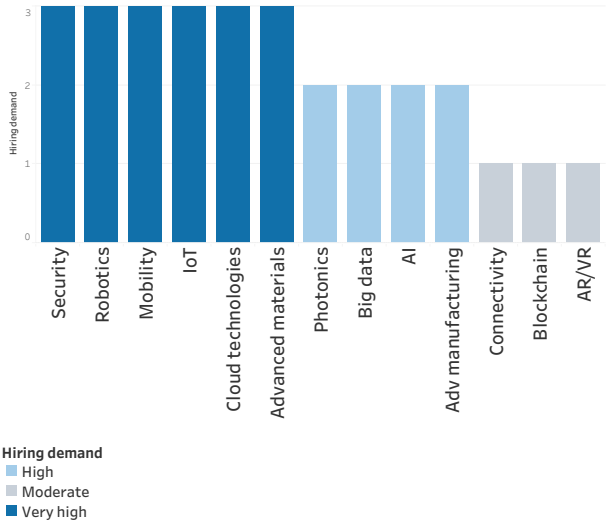
Figure 25: Top countries with the largest one-year growth in digital technologies (AR/VR, AI, big data, blockchain, cloud, connectivity, mobility, robotics, security, 2018-2019



Source: Technopolis Group based on LinkedIn analysis

Based on the skills requirements of the online job advertisements posted on LinkedIn by European automotive firms, we observe that the fields with 'very high hiring demand' as captured in LinkedIn include the following: Security, Robotics, Mobility, IoT, Cloud and Advanced materials. Hiring demand is defined as the share of job ads published on LinkedIn and requiring the specific skill.

Figure 26: Hiring demand in automotive, Dec 2019 – March 2020



Source: Technopolis Group based on LinkedIn analysis

Section 5

5. Future outlook: challenges and opportunities

5.1 COVID-19 pandemic

The serious challenge of the COVID 19 crisis and its impact on the European automotive industry has brought both production and sales to a sudden halt in most of the EU - and globally.[63] The effects of the corona pandemic result in a 76% reduction in new registrations of passenger vehicles in the EU27 compared to the previous year (as of April 2020). Although each of the EU27 countries recorded double-digit declines in April, Italy and Spain felt the biggest impact with 97.6% and 96.5%, respectively.[64] As of April 2020, over 1.1 m jobs of Europeans (out of a total of 2.6 m direct manufacturing jobs) were affected by factory closures in car manufacturing due to the pandemic.[65] The ACEA (European Automobile Manufacturers' Association) has identified four guidelines for the successful re-launch of the automotive industry in the wake of the corona pandemic, such as the coordinated resumption of vehicle production, stimulation of demand and accelerating investments in the infrastructure for recharging and refuelling.[66]

5.2 New emission regulations

Despite resistance from the automotive industry and some EU27 Member States[67], the new EU regulation on CO_2 emissions performance standards has been in force since January 1st 2020, affecting passenger cars and new vans, which are responsible for 12% and 2.5% of total CO2 emissions in the EU, respectively. The new regulation sets EU-wide CO_2 emission targets for the years 2025 and 2030, which are defined from the 2021 starting points. Percentage CO2 emission reductions of 15% from 2025 and 37.5% from 2030 apply to all newly registered passenger cars, while CO_2 emissions from vans are to be reduced by 15% from 2025 and 31% from 2030.[68] The law also requires that in the future it will be possible to assess emissions over the entire life cycle of motor vehicles.[69]

5.3 High investment needs

The automotive industry is the largest investor in research and development in the EU with 28% of the total R&D expenditure, investing €57.4 bn annually.[70] A large share of this investment goes into the area of automotive safety and in particular into automated driving features. A trade surplus of €84.4 bn was generated by the automobile industry in the EU in 2018.[71] These economic challenges and rapid changes demand major investments in research and development in order to keep up with the increasing competition.

5.4 Digital divide

The digital transformation brings many opportunities for the European economy and society. It influences activities, processes and the organisational culture. Nevertheless, challenges also arise for the employees in the future. The analysis of the EU27 skills competencies confirms a high demand for IT-related skills in the automotive industry. European companies seem to have trouble in recruiting staff with adequate competencies in information communication technology (ICT). According to estimates, approximately 90% of all jobs today require basic digital skills in order to be able to perform their jobs. However, 20% of the EU population and one third of the working population lack these digital skills.[72] In order to solve the EU's challenge of skill shortages in the automotive industry, several aspects are to be considered.
To improve the general understanding, a framework for standardised job roles and associated skills is necessary. In addition, labour mobility and transferability need to be improved across the value chain. A better functioning apprenticeship market should be developed in the EU. Additionally, an improved recognition of non-formal and informal learning is recommended.[73] In order to address the skills needs of the automotive industry, the European Commission has developed several initiatives, such as the "blueprint for sectoral cooperation on skills"[74], which aims to develop concrete actions to address qualification

[63] European Automobile Manufacturers' Association 2020b.
[64] European Automobile Manufacturers' Association 2020e.
[65] European Automobile Manufacturers' Association 2020d.
[66] European Automobile Manufacturers' Association 2020a.
[67] European Parliament 27/03/2019.
[68] European Commission 2019a.
[69] European Parliament 27/03/2019
[70] European Automobile Manufacturers' Association 2019a, p. 3.
[71] European Automobile Manufacturers' Association 2019a, p. 41.
[72] European Commission 2019d.
[73] European Commission 2019g, p. 1.
[74] European Commission 2017a.

needs in response to skills mismatches, the "COSME"[75] project, which targets the skills needs of SMEs in the automotive sector, or the Alliance for Batteries Technology, Training and Skills (ALBATTS)[76], which aims to identify and develop relevant skills arising from the new requirements of electric mobility.

5.5 Developing and emerging markets

The automotive industry is deeply rooted in the European Union's history and plays an essential role in the global economy, employing a significant number of 13.8 m workers[77] and accounting for a significant share of external trade. Fast-growing developing countries can be a chance to increase the demand for vehicles, penetrate the new markets and thus increase the competitiveness of the EU automotive industry. At the same time, increasing vehicle production in developing and emerging markets create the pressure to face global competition. Vehicle manufacturers work closely with (advanced) systems suppliers, who are responsible for a high share of value added. As the production of vehicles requires metals and other materials, the automotive sector is strongly interconnected with other industries.[78] A current example of the EU's dependence on other countries is the demand for battery cells or the associated raw materials triggered by increasing electrification. European car manufacturers are highly dependent on battery cell imports, exposing them to high costs and supply chain risks. Accordingly, the EU must reduce current dependencies and secure the sources of the relevant materials in a long-term and sustainable manner.[79]

5.6 Software and services

Data-driven innovation transforms the automotive industry on various levels, thus creating many challenges as well as new opportunities for future growth in the European Union. The importance of connectivity and autonomous driving technologies is increasing. Automotive production is more and more oriented towards using data, which offers a new potential for the EU to maintain its strong position in Advanced Manufacturing technologies. New service models, such as car sharing, will continue to influence the future of the automotive industry and transform the traditional forms of ownership.

Digitised, networked and automated or autonomous vehicles require highly integrated hardware and software stacks. The dependence of European manufacturers on different suppliers who bring along individual software solutions and standards is a challenge for the integration of the different systems.

In addition, data collection and networking services are still not considered an integrated part of the vehicle, which has a negative impact on the ability of vehicle manufacturers to collect data, e.g. for the maintenance or training of neural networks.

5.7 Innovation in new technologies

Advanced technologies play a crucial role in the future of Europe's automotive companies and create new innovation prospects. The greatest technological focus of the European Union's automotive industry is on Advanced Manufacturing, mobility as well as AI and Photonics. Although the EU countries are currently quite advanced in this area, other countries are clearly on the rise.

[75] European Commission 2019g.
[76] albatts 2020.
[77] European Automobile Manufacturers' Association 2019a, 11ff.
[78] Vošta and Kocourek 2017, 69ff.
[79] European Commission 2019f, 2ff.

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. The project provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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