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Is the European automotive industry ready for the global electric vehicle revolution?

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Executive summary

THE AUTOMOTIVE SECTOR is currently at the centre of a global transformation, driven by four key trends: electrification, autonomous driving, sharing and connected cars. While each of these interconnected trends is already visible in daily life, their full deployment is not yet guaranteed, nor is the speed of take-up.

THIS POLICY CONTRIBUTION investigates the position of the European automotive industry in a scenario in which electrification substantially progresses.

THE RESULTS ARE encouraging for Europe: EU companies entered late the global electric vehicle race, but on the basis of our analysis it is not yet too late for them to catch up and make the best of this change.

EUROPEAN CAR MANUFACTURERS can rely on a large internal market, long experience in automotive manufacturing and a portfolio of research and development projects and patents that is diversified across various power-train technologies. But if Europe wants to succeed in the global electric vehicle race, its automotive industry will have to move into higher gear to meet the global – notably Chinese – competition. Nevertheless, industry needs the proper framework conditions as the basis for more ambitious investments in electrification – as examples such as Norway or China demonstrate.

THIS POLICY CONTRIBUTION formulates a broad policy framework for deployment and production of electric vehicles in Europe, combining demand and supply-side instruments. Europe cannot follow China in the adoption of centrally-planned industrial policy measures. But it certainly can and should do more to stimulate the transformation of its automotive industry through more ambitious policies.

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1 Introduction

The automotive sector is important for the European Union economy. Accounting for 4 percent of EU GDP, it employs 8 million people and ranks among the main EU sectors in terms of exports and research and development (R&D). And because of its long supply chain, the sector has a significant multiplier effect on the EU economy.

Four disruptive trends are generally considered to be reshaping global mobility and consequently the global automotive industry: electrification, autonomous driving, sharing and connected cars. While each of these interconnected trends is already starting to be visible in daily life, their full deployment is not yet guaranteed, nor is the speed of their take-up.

We focus on one of these trends: electrification.

Electric vehicles (EVs) are increasingly considered a key solution to decarbonise the transport sector, which is becoming the main obstacle to the achievement of the EU's vision for a climate neutral Europe by 2050 (European Commission, 2018). Road transport is responsible for about three quarters of the EU transport sector's emissions. To meet the current EU decarbonisation targets, transport would actually have to be completely decarbonised shortly after 2050. This creates a big window for EVs.

In addition, decarbonising road transport would also be decisive for improving air quality in cities, which remains a fundamental challenge for public health in Europe. Air pollution is responsible for more than 400,000 premature deaths each year in Europe (EEA, 2016). Pollution from road transport is a key contributor to this problem.

EVs are increasingly being spotted on EU roads. But the real EV success story is undoubtedly China, which has rapidly established itself as the global leader in EV manufacturing and where the internal EV market is growing exponentially. Meanwhile, Europe has lagged behind in terms of both manufacturing and deployment.

We assess the position and prospects of the European automotive industry in the global EV race in a context in which the scope and speed of the 'EV revolution' remains uncertain. To do so, we look at automotive R&D investment and the latest available versions of patents databases.

This analysis reveals an encouraging picture, in which Europe, although not a frontrunner, has not yet lost its leading position in automotive innovation. With the right continuous R&D focus in the EU automotive supply chain sector and with the right policy framework on the government side, the European automotive sector could not only meet the challenge of the global EV revolution, but even drive it forward.

2 The importance of the automotive sector for value added

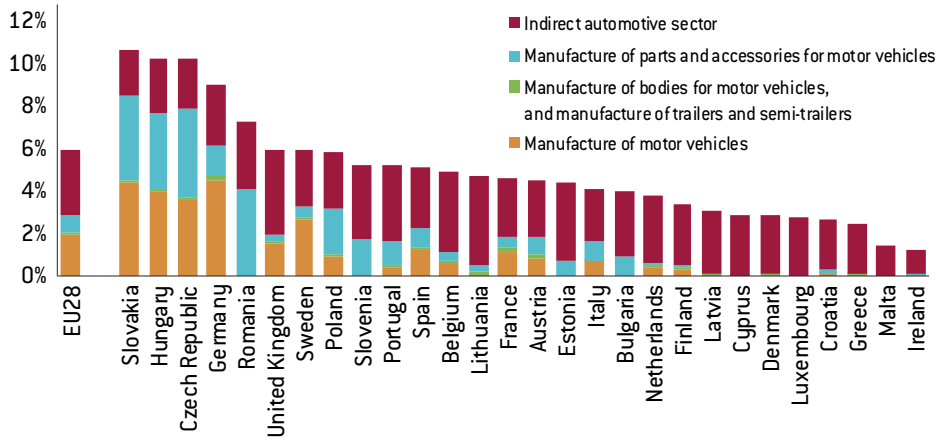
Value added

Value added is created both in the direct and indirect automotive sectors. The 'direct' sector includes the manufacture of (1) motor vehicles, (2) parts and accessories to motor vehicles, and (3) bodies for motor vehicles, trailers and semi-trailers. The indirect sector consists of the sale of motor vehicles, maintenance and repair of motor vehicles, sale of motor vehicle parts and accessories, retail sale of automotive fuel in specialised stores, and renting and leasing of motor vehicles.

In the EU, the value added of all automotive sectors is considerable. In 2015, it represented almost 6 percent of overall value added, making it larger than other major sectors such as pharmaceuticals and machinery equipment manufacturing. In some EU countries (Slovakia, Hungary, the Czech Republic and Germany: henceforth the BIG4), the automotive sector accounts for more than 8 percent of their total value added (Figure 1).

The indirect sector accounts for half of overall automotive value added in the EU (Figure 1). The share of the indirect sector is uniform in all EU countries and is generally the largest component of overall automotive value added. When looking at the direct sectors, the manufacture of vehicles generates around 2 percent of total value added in the EU. It is especially important in the BIG4. The manufacture of vehicle parts also accounts for a large amount of value added in the BIG4 and in Romania, Slovenia and Portugal.

Figure 1: Share of the automotive sector in total value added (2015)

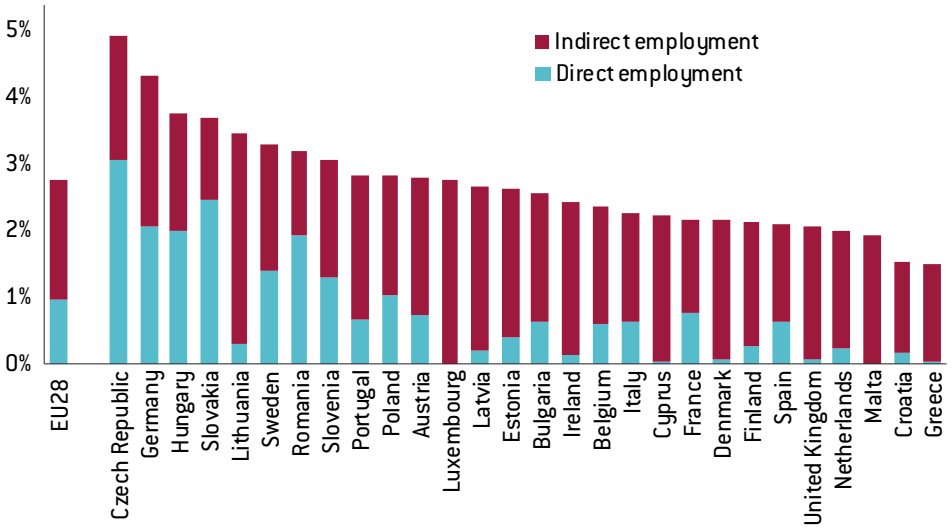


Source: Bruegel based on Eurostat. Note: The indirect automotive sector consists of 'Sale of motor vehicles' + 'Maintenance and repair of motor vehicles' + 'Sale of motor vehicle parts and accessories' + 'Retail sale of automotive fuel in specialised stores' + 'Renting and leasing of motor vehicles'. 'Motor vehicles' include passenger cars, commercial vehicles (vans, lorries and over-the-road tractors for semi-trailers), coaches, buses, trolley-buses, snowmobiles, golf carts, amphibious vehicles, fire engines, street sweepers, travelling libraries, armoured cars, concrete-mixer lorries, ATVs, go-carts and race cars. Also included are motor vehicle engines (other than electric motors) and chassis. 'Value added at factor costs' is the gross income from operating activities after adjusting for operating subsidies and indirect taxes. Value adjustments (such as depreciation) are not subtracted.

Employment

In terms of employment, the automotive sector accounted for almost 3 percent of the EU's labour force in 2015 (Figure 2). In the EU and in most EU countries, the indirect sectors account for the greatest share of automotive employment, as they include the more labour-intensive services such as sales and maintenance. Employment in the capital-intensive direct sectors in the EU is concentrated in a few countries. The BIG4 accounts for most of the EU's direct automotive employment.

Figure 2: Share of the automotive sector in total employment in 2015

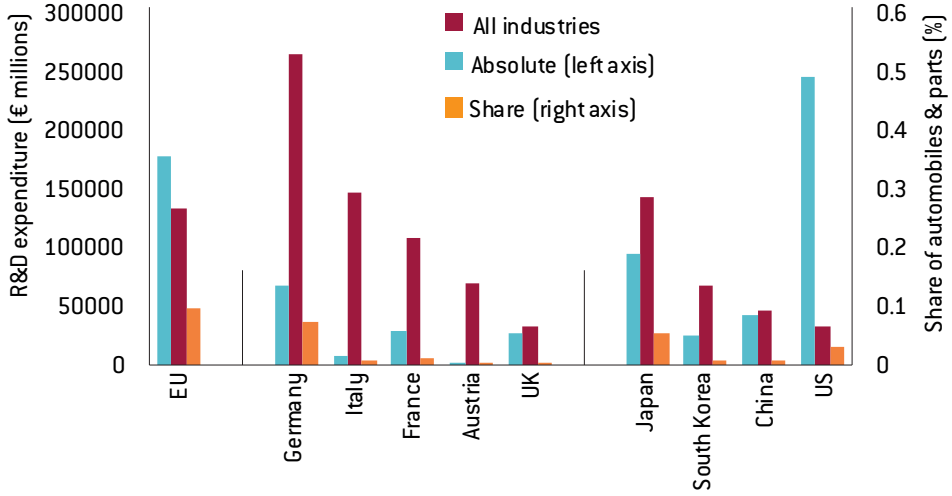


Source: Bruegel based on Eurostat. Note: 'Direct employment' corresponds to the number of people employed in the 'Manufacture of motor vehicles' + 'Manufacture of bodies for motor vehicles and manufacture of trailers and semi-trailers' + 'Manufacture of parts and accessories for motor vehicles'. 'Indirect employment' corresponds to the number of people employed in the 'sale of motor vehicles' + 'maintenance and repair of motor vehicles' + 'sale of motor vehicle parts and accessories' + 'retail sale of automotive fuel in specialised stores' + 'renting and leasing of motor vehicles'. Total employment corresponds to individuals aged 15 to 64 years.

Research and development

The automotive sector is very important for corporate R&D in Europe. European automotive companies listed in the *EU Industrial R&D Investment Scoreboard*[1] spent more than €45 billion per year on R&D between 2013 and 2016, amounting to more than 25 percent of all R&D spending by European scoreboard firms (Figure 3). German firms spend the most in the world on automotive R&D. German automotive firms spend around €35 billion per year on R&D, or 78 percent of all EU automotive scoreboard R&D. This represents more than half of German scoreboard firm spending on R&D.

Figure 3: Automotive and parts R&D expenditure (average 2013-2016) of scoreboard firms



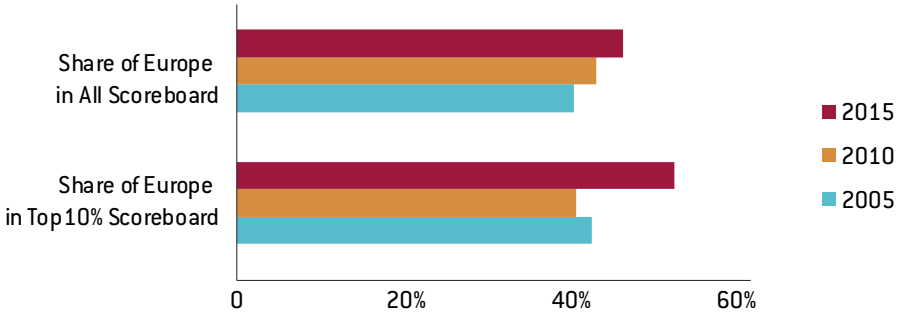
Source: Bruegel based on *EU Industrial R&D Investment Scoreboard* 2013-2016 and *EU Industrial R&D Investment Scoreboard* 2014. Note: The R&D data are firm-level, obtained from *EU Industrial R&D Investment Scoreboard* WORLD - 2500 companies.

1 The *EU Industrial R&D Investment Scoreboard*, created by the European Commission's Joint Research Centre, includes R&D spending data from the top 2500 R&D-spending firms. By relying on the R&D Scoreboard for R&D figures, we exclude the R&D spending of many small firms.

Internationally, only Japanese companies spend similar amounts on automotive R&D: Japanese scoreboard firms from the automotive sector spend more than €25 billion on R&D, or almost 30 percent of all R&D spending by all Japanese scoreboard firms. In the US, these figures amount only to €15 billion and 5 percent. South Korea and China account for even smaller absolute amounts and shares.

European automotive firms have traditionally held a dominant position in R&D, with the top 10 percent of European automotive R&D spenders proportionally outspending the biggest automotive spenders from other parts of the world (Figure 4). This strong position has even expanded over time.

Figure 4: Europe's position in global corporate automobile R&D



Source: Bruegel based on *EU Industrial R&D Investment Scoreboard* 2015.

Volkswagen has traditionally been the corporate R&D leader in the sector, by a substantial margin: in 2015 it represented about 13 percent of corporate automotive R&D, which is almost double the share for Toyota, the second largest spender.

Table 1: Ranking of top automotive R&D spending companies

Rank 2015			Share of sector R&D	Share of sector sales	Sector R&D, cumulative share
1	Volkswagen	Germany	12.62%	8.49%	13%
2	Toyota Motor	Japan	7.46%	8.62%	20%
3	General Motors	USA	6.39%	5.57%	26%
4	Daimler	Germany	6.05%	5.95%	33%
5	Ford Motor	USA	5.71%	5.47%	38%
6	Honda Motor	Japan	5.09%	4.43%	43%
7	Robert Bosch	Germany	4.82%	2.81%	48%
8	BMW	Germany	4.79%	3.67%	53%
9	Fiat Chrysler Automobiles	Italy	3.81%	4.40%	57%
10	Nissan Motor	Japan	3.76%	3.70%	61%
32	Tesla	USA	0.59%	0.15%	
38	Great Wall Motors	China	0.36%	0.41%	
46	Guangzhou Motors	China	0.25%	0.17%	

Source: Bruegel based on *EU Industrial R&D Investment Scoreboard* 2015.

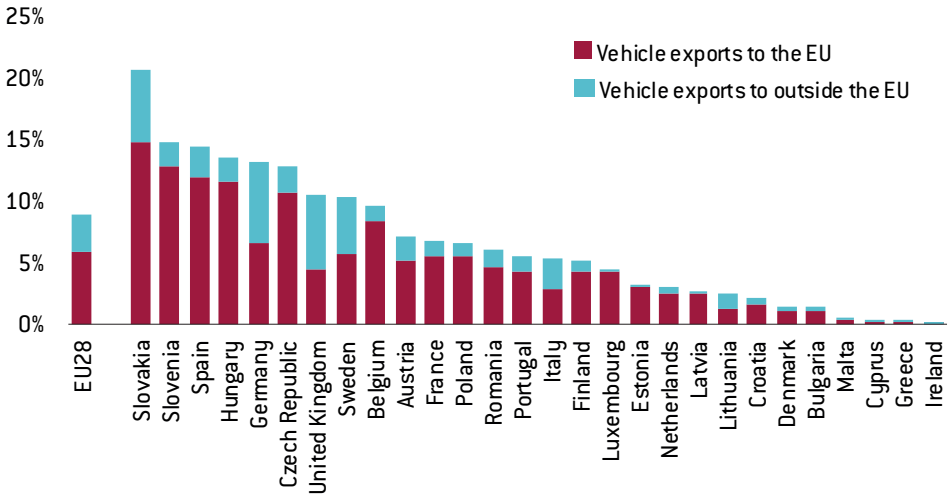
In general, the sector is quite stable at the top. The ranking of top automotive R&D spending companies has remained largely unchanged in recent years; however some young firms in the sector have expanded quickly their R&D spending. The most important of these young companies come from outside the EU: US-based Tesla and several Chinese firms, which with considerable increases in their R&D spending, have climbed several dozen places in the scoreboard ranking (Table 1).

External competitiveness

Vehicles account for 9 percent of EU exports (Figure 5). Vehicles account for more than 10 percent of exports from the BIG4, but also from Slovenia, Spain, the United Kingdom and Sweden. About two-thirds of EU vehicle exports are traded between EU countries (intra-EU). The EU is the major destination and source for the automobiles of most member states. Extra-EU vehicle exports are as large as intra-EU exports only for Germany, Sweden and Italy. The UK is the outlier country, exporting most of its vehicles to non–EU countries.

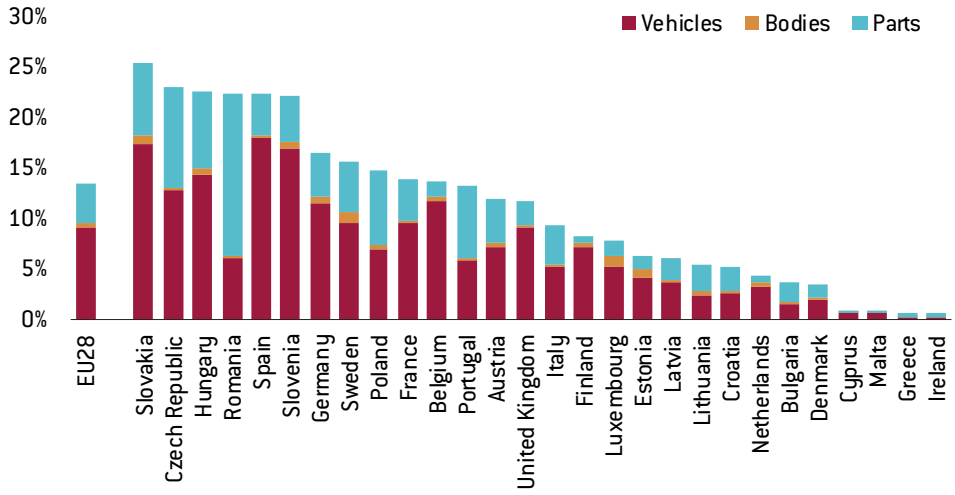
If exports of vehicle bodies and vehicle parts are also taken into account, total automotive exports account for almost 15 percent of intra-EU exports, of which one-third comprises vehicle parts. Trade in vehicle parts reflects the integration of European value chains. For smaller countries, a substantial part of intra-EU automotive trade is in parts (ie suppliers in European value chains). This is the case for the Czech Republic, Romania, Poland, Hungary, Slovakia and Portugal.

Figure 5: Motor vehicle exports to the EU and to non–EU countries as a share of total exports of all goods (2017)



Source: Bruegel based on Eurostat. Note: 'Motor vehicles' are defined as product code 291 on Eurostat.

Figure 6: Motor vehicle, body and parts exports to EU countries as a share of total exports of all goods to EU countries (2017)

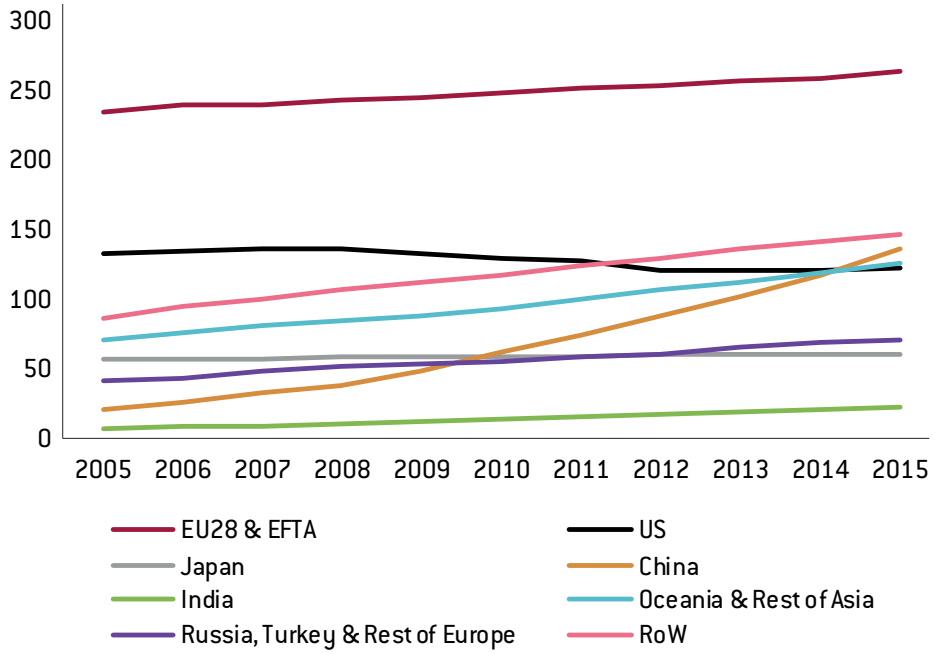


Source: Bruegel based on Eurostat. Note: 'Motor vehicles', 'Bodies' and 'Parts' are defined as product codes 291, 292, and 293 respectively on Eurostat.

The power of the EU as a market

The strong position of the EU in the global automotive sector also comes from its market power. The EU and European Free Trade Area countries (Iceland, Liechtenstein, Norway, and Switzerland) combined have the world's largest stock of passenger cars, having grown from 235 million to 263 million cars between 2005 and 2015 (Figure 7). By contrast, the US car stock is decreasing. The number of cars in use in Japan has remained stable in the past decade but is relatively small (61 million in 2015). But the biggest growth comes from China, which is now already similarly sized to the US market. Growth in the Indian market has so far been below expectations.

Figure 7: Passenger cars in use

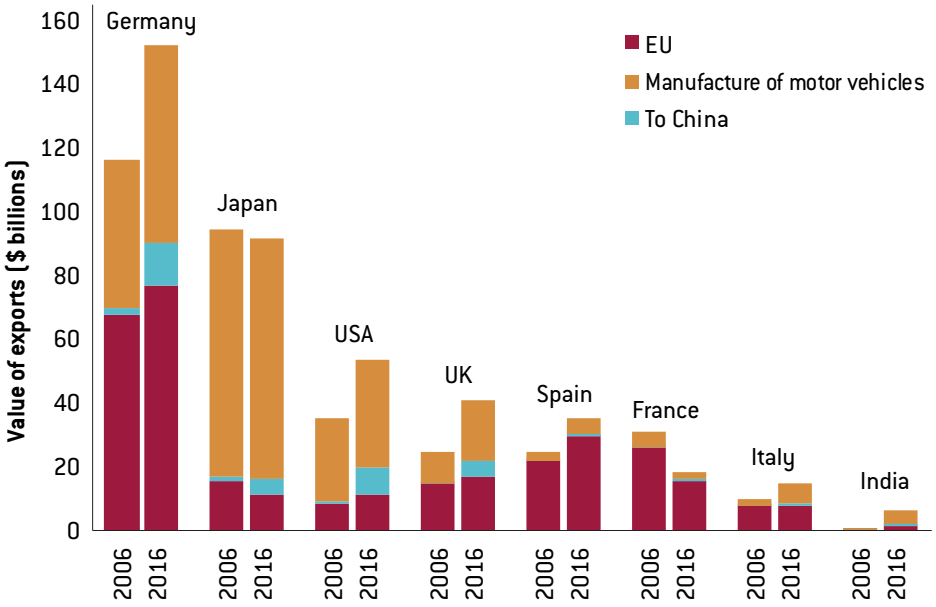


Source: Bruegel based on OICA.

On the supply side, the EU was traditionally the largest car producer in the world but has been overtaken by the spectacular growth of car manufacturing in China. Between 2006 and 2016, Chinese production shot up from five million to almost 25 million cars per year. China's rise has not crowded out EU production volumes though, which were similar in 2016 (16.9 million) and 2006 (16.5 million). This can largely be attributed to stable production levels in Germany.

Germany remains the world's largest exporter, accounting for 20 percent of global car exports[2]. Figure 8 shows that German exports have risen to all destination markets, including intra-EU, but especially to China. French exports have declined and France has missed out on the Chinese market growth. The growth in UK exports is mostly to non-EU countries (not including China).

Figure 8: Value of passenger car exports in 2006 and 2016 ($ billions)



Source: Bruegel based on ComTrade. Note: 'Passenger cars' = Motor vehicles for transport of persons (except buses) (HS code: 8703).

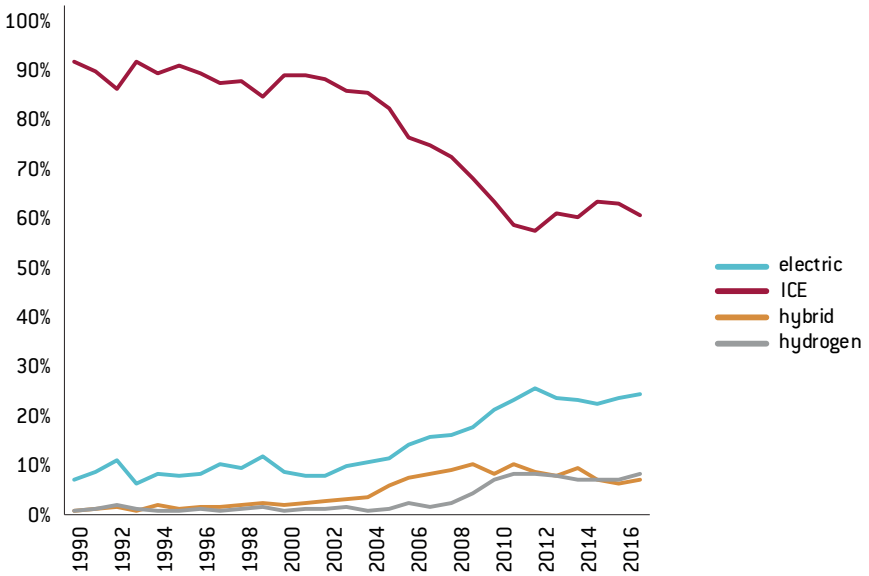
3 The trend towards electric vehicles

The electrification of vehicles has become a key trend in the automotive sector, driven by clean energy and climate change concerns and policy interventions – such as support for zero-emission vehicles and carbon taxes – intended to reduce greenhouse gas emissions[3]. Figure 9 shows how patenting of power-train technologies, which was dominated by internal combustion engine (ICE) technology, has started to shift towards cleaner power-train technologies, of which EV technology has become the most important.

2 Calculated manually using data from UN Comtrade.

3 In fact, the recent electrification trend can be seen as a rebirth. In the early days of vehicle manufacturing, electric motors and the internal combustion engine were both in the running to become the dominant power train, but low petroleum prices and the problem of the short range of electric vehicles because of battery technology bottlenecks, the internal combustion engine became dominant.

Figure 9: Patenting of major power-train technologies



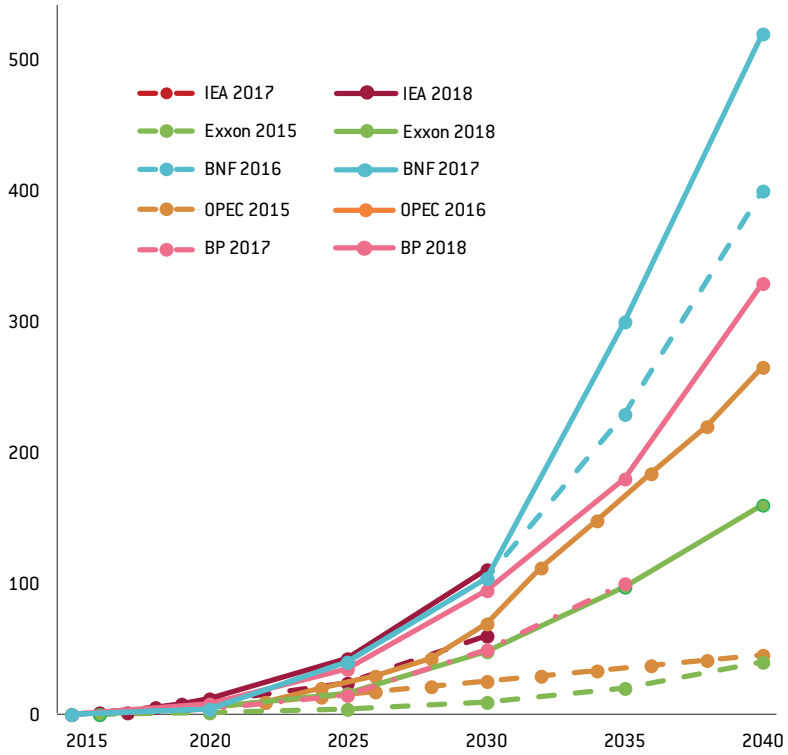
Source: EPO Patstat, April 2018 edition. Note: We count all patents filed under the Patent Cooperation Treaty (PCT) in all possible patent offices worldwide. By doing so, we only capture 'high-quality' patents and avoid double counting. Using only PCT patents, we might miss local patenting trends but ensure comparability between the different jurisdictions. Patents are classified according to four different power-train technologies. We rely on the classification in Aghion *et al* (2016) that divides power trains into electric motor technologies, hybrid motor technologies, hydrogen motor technologies and internal combustion engine (ICE) technologies. Classification is done via the International Patent Classification (IPC) code system. The patent codes used for the classification can be found in Annex 1.

As EV technology has developed, technological improvements have reduced EV production costs, in particular by reducing battery costs, further nurturing the development of the EV market. Lithium-ion (Li-ion) is the technology of choice for EV batteries, and is expected to retain this dominant position during the next decade (IEA, 2018). Prices for Li-ion batteries have significantly decreased since their introduction in the 1990s, whether for electronics, for residential and utility storage, or for EV-related purposes. Alongside the falling cost of Li-ion technology, the scaling up of battery manufacturing capacities in recent years has been a key driver of cost reductions for batteries.

EVs are expected to proliferate in the future. To meet commitments under the Paris Agreement, more governments will increase their support for zero-emission vehicles, ban dirty vehicles and support the deployment of EVs and their charging infrastructure. At the same time, EV technology and manufacturing costs are likely to continue to fall as production expands. The IEA predicts that the main driver of battery cost reduction will be the scaling up of manufacturing capacities (IEA, 2018). Further cost reductions and technology improvements will further boost the development of EV markets.

Figure 10 depicts various deployment forecasts. All agree on high future growth rates, but the most recent forecasts are significantly higher. For instance, BNEF (2017) anticipates more than 500 million EVs globally by 2040 – a significant upward adjustment compared to BNEF's prior forecast in 2016.

Figure 10: Global EV deployment forecasts



Source: Bloomberg New Energy Finance.

The impact of EVs on automotive supply chains

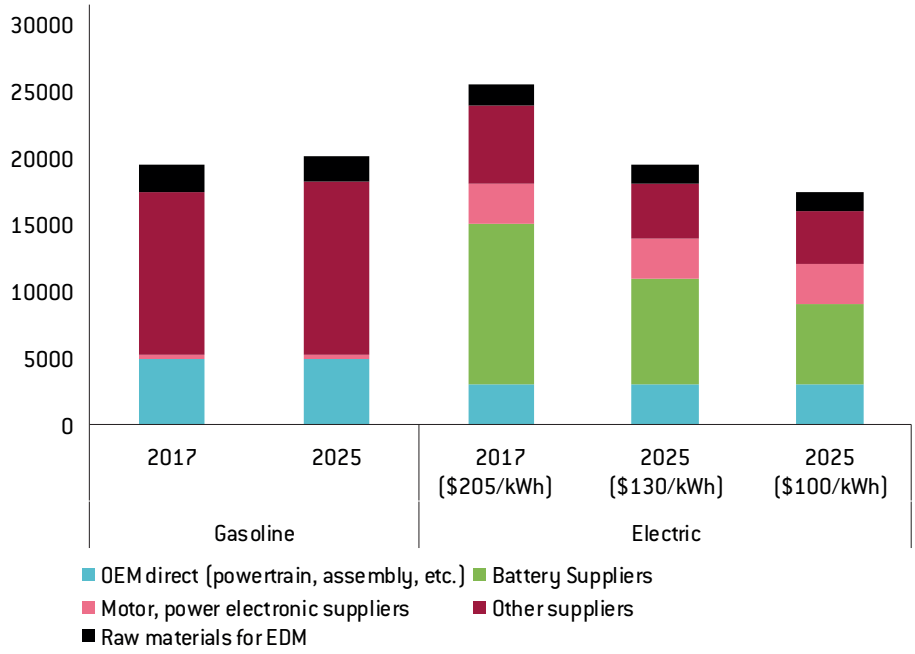
EV market growth will have major consequences for traditional automotive supply chains, which are based on internal combustion. At the manufacturing stage, EVs represent a paradigm shift compared to ICE vehicles. The mechanical complexity of EVs is less, reducing manufacturing costs the number of workers required in the EV manufacturing process. This could mean a significant impact on jobs, requiring a shifting of skills from ICE to EV production and also reducing the number of manufacturing jobs.

In addition, EVs requires less maintenance than ICE vehicles as fewer parts need to be replaced over vehicles' lifetimes (UBS, 2017). This could have significant consequences for after-sales service providers that generate large shares of their revenues from service and maintenance (UBS, 2017; McKinsey, 2014).

The EV supply chain is also different from that for ICE vehicles. By comparing the content of a Chevrolet Bolt (EV) and a Volkswagen Golf (ICE), UBS (2017) found that almost 60 percent of the content of the Chevrolet Bolt originated from outside the traditional supply chain, the biggest difference being the battery packs in EVs (Figure 11). A value shift in the automotive supply chain implies challenges for EU carmakers and traditional suppliers. For one, it could jeopardise huge sunk ICE-related investments (eg in advanced diesel efficiency technology). There is also a risk that traditional suppliers and carmakers only capture a small share of the value of EVs. This could be especially likely if they lack unique competence in battery production and electric motor manufacturing.

However, EVs also provide new opportunities within the automotive sector. The transformation of the supply chain implies that new suppliers will emerge and capture value, especially in terms of critical battery technology. Furthermore, as EV production costs continue to fall, lower consumer prices will result in higher sales volumes. This can translate into greater economies of scale for manufacturers, further increasing the returns on EV-related investments (UBS, 2017). In addition, rapidly falling battery costs can improve margins for manufacturers of electric motors (McKinsey, 2016).

Figure 11: Breakdown of the manufacturing cost of ICE and electric vehicles ($)



Source: UBS (2017).

Even if in total EVs have a positive effect on automotive supply chains, the disruptive negative effects might be concentrated in certain regions affected strongly by local suppliers disappearing or relocating. Transport & Environment (T&E, 2017) aimed to quantify the income and employment effects of the transition to EVs. T&E (2017) highlighted that the EU will likely suffer job losses if traditional suppliers are unable to switch technologies or if engine and component manufacturers continue to invest in traditional power-train technologies. In that case, the overall number of jobs in the automotive sector would decrease. However, should the European automotive sector be able to produce competitive EVs, the overall number of jobs in the automotive sector could even grow.

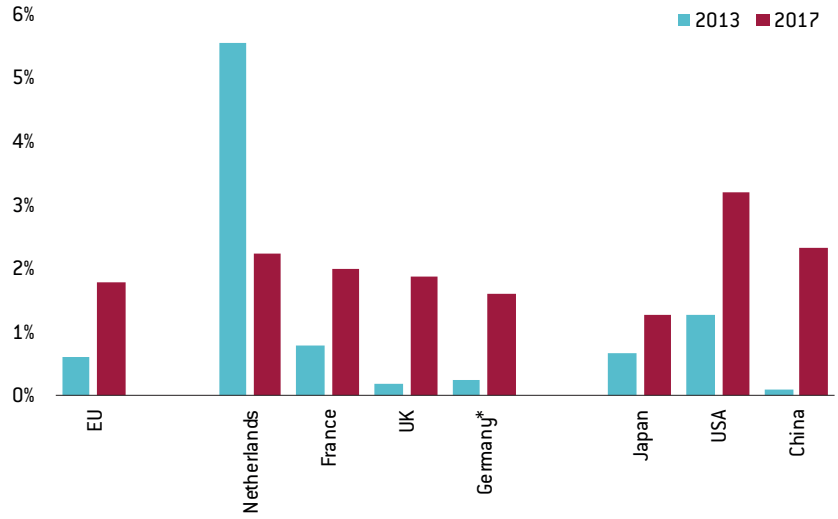
4 The EU and electric vehicles

The EU and the global demand for EVs

Is the EU well-positioned to respond to the EV revolution? Data on registrations of EVs reveals two main features: the global EV market remains to date a small part of the overall car market, but it is growing rapidly.

In all major countries, EVs in 2017 had shares well below 5 percent of total vehicle registrations (Figure 12). Only in Norway did the share substantially exceed 5 percent (making Norway an outlier, not shown in Figure 12). The high share of registrations in Norway is explained by a broad, time-consistent policy plan. Through a series of small policy steps, Norway has put in place an effective policy mix, covering a broad range of interventions: regulations, direct investment and fiscal advantages. Such a long-term and broad commitment has proved effective in changing consumer behaviour. The result is striking. The Norwegian EV share of the total vehicle fleet has grown exponentially since 2010, from almost zero in 2010 to 25 percent in 2017.

Figure 12: EV registrations as a share of total passenger car registrations, selected countries



Source: Bruegel based on the following data sources: *EV registration data:* https://www.zsw-bw.de/en/media-center/data-service.html#c6700 (which in turn sourced data from: "German Federal Motor Transport Authority, ZIV Zweirad-Industrie-Verband, European Alternative Fuel Observatory, Hybridcars.com, EV Sales, EV Norway, Avere France, FCE, EV Volumes, Department for Transport UK, Society of Motor Manufacturers and Traders (SMMT), CAAM, Rijksdienst voor Ondernemend Nederland, Bil Sweden, Green Car Reports, auto-schweiz"). *Total registration data:* OICA. Note: EVs in the figure are battery-electric vehicles (BEV) and other electric vehicles (such as Plug-in Hybrid electric vehicles, PHEV). * The EV registrations data for Germany are rounded by the source. 'EU' consists of the UK, France, the Netherlands, Germany, Sweden and Spain

However, Figure 12 also shows the strong dynamic in the EV market. EV registrations as a share of total car registrations increased in all countries between 2013 and 2017, but more in some than in others, with the Chinese market showing the biggest increase in penetration of EVs.

Figure 13 shows EV registrations in a number of countries as shares of global EV registrations. While the EU with 23 percent and the US with 48 percent dominated the worldwide EV market in 2013, by 2017 China had a clear lead, with 48 percent of global EV registrations. Far behind were the US with 16 percent and the EU28 with 15 percent. Japan's share dropped from 13 to 5 percent. Within the EU, Germany and the UK increased their shares of the global EV market, while France and early adopter the Netherlands experienced declines between 2013 and 2017.

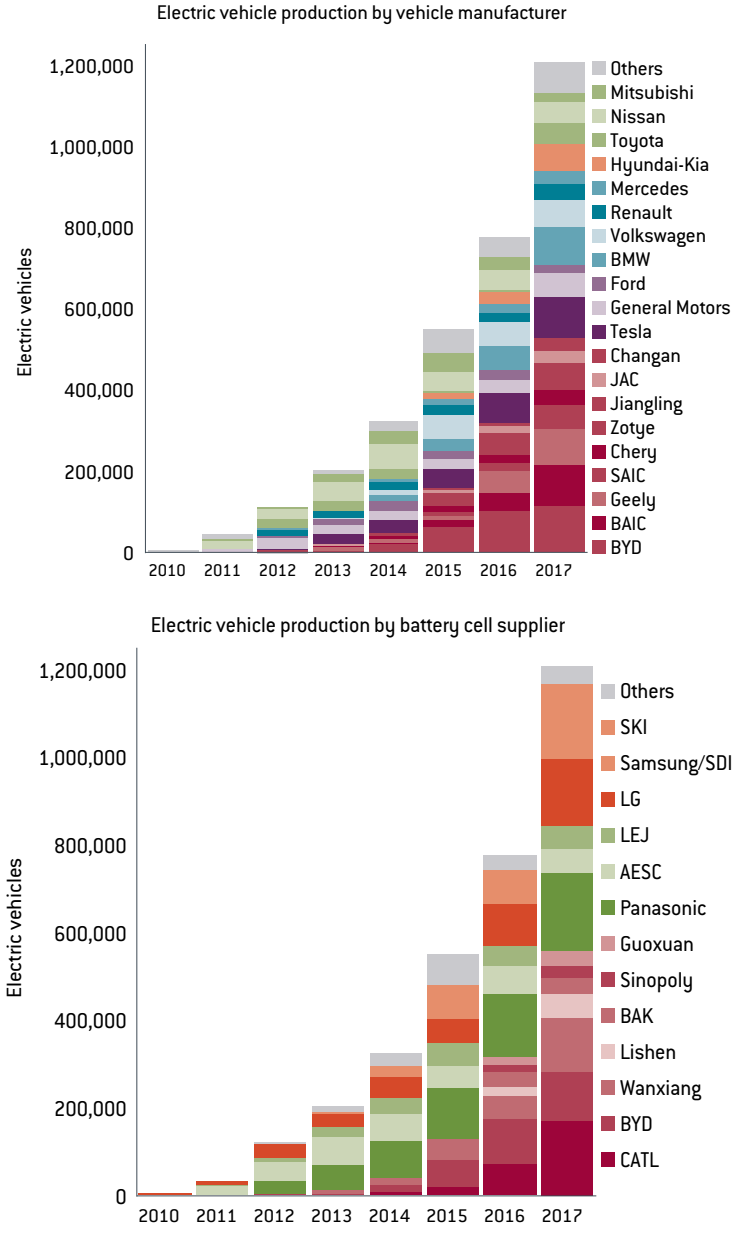
Figure 13: Share of new EV registrations of country in world new EV registrations

Source: Bruegel. For data sources and notes, see Figure 13.

The EU and the global manufacturing of EVs

There is a crucial trend in global EV manufacturing: over the last few years, China has rapidly established itself as the global leader, leaving Europe and other regions behind. The largest EV manufacturers are new Chinese firms (Figure 14, top panel). Japanese and US firms were early movers, but only Tesla is currently a leading manufacturer in the global EV market. German firms entered late, but are catching up with the early movers.

Figure 14: EV production by vehicle manufacturer and by battery manufacturer



Source: ICCT (2018, p. 5).

In global EV battery manufacturing (Figure 14, lower panel), a crucial part of the EV value chain, China's leadership is even more evident. The first mover, Japan, was rapidly surpassed by China between 2014 and 2017 – as Chinese companies proliferated and grew rapidly, as along with Korean firms. No EU or US firms are among the world's major battery producers.

This impressive rise of China in EV manufacturing has been driven by the country's strong industrial policy in the field (Box 1).

Box 1: Policies to stimulate EV demand: the Chinese Case

China has made the EV industry a priority for its 'Made in China 2025' industrial policy, which envisages a significant global market share in 10 high-tech industries. In this framework, the Chinese government – at both central and local levels – strongly supports the manufacturing of EVs, through measures such as:

1. Ambitious EV targets, requiring carmakers to meet certain EV quotas in their production[4];
2. Generous fiscal subsidies for EV manufacturers, based on the EV's driving range per charge, to foster innovation;
3. Requirements for international carmakers to manufacture EVs in China to access the market;
4. Strong financial incentives for EV purchasers;
5. Extensive charging infrastructure deployment.

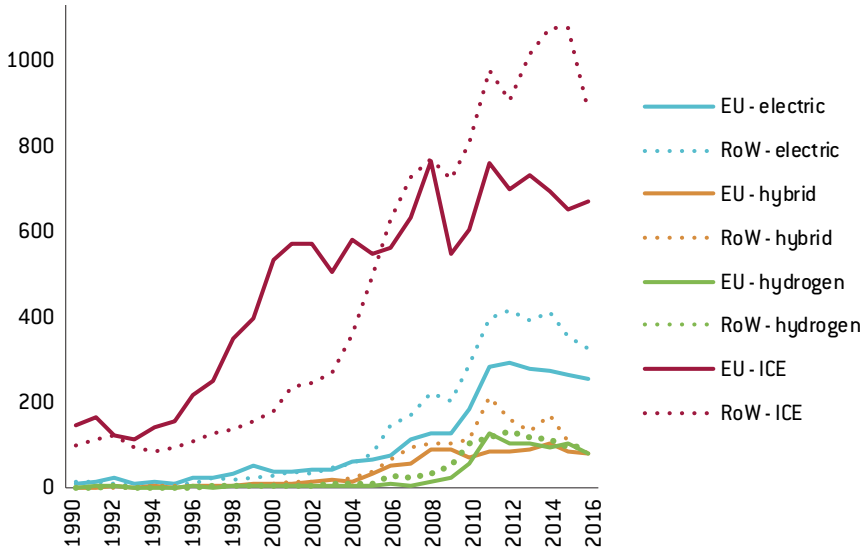
Thanks to this strong EV industrial policy, China has secured large investments in EV manufacturing plants from Chinese firms and from foreign (notably European) carmakers. For instance, in 2017 China secured €21.7 billion of investment from European carmakers in EV manufacturing, while Europe secured only €3.2 billion (T&E, 2018).

The EU and EV technology development

Patent data also shows that the EU was not a first mover in EV technology development. EV technology patenting activity, while mostly flat until 2005, kick-started globally in 2005 and began to grow in Europe in 2009 (Figure 15). Meanwhile, the EU and the rest of the world continue with heavy patenting of ICE technologies.

The dominance of ICE technology in EU automotive patents before 2009 has since been changed to a more balanced position across all power-train technologies – electric, hybrid, hydrogen and ICE (Figure 15, lower panel). For instance, the number of EU EV patents grew from 124 in 2008 to 290-250 per year between 2011 and 2016.

Figure 15: EU versus rest-of-world in major power-train technology patents



Source: Bruegel based on EPO Patstat, April 2018 edition.

4 China passed in 2017 a law mandating carmakers (with annual sales greater than than 30,000 vehicles) to meet fuel consumption and EV production targets in order to qualify for new energy credits. Manufacturers that fail to hold a given proportion of these credits are fined or must buy credits from other manufacturers.

In terms of the current specialisations of countries in power-train technologies, EU overall is well spread across the various technologies. Within the EU, Germany is by some margin the major patenting country. Like the other major patenting countries, Japan and Korea, it is spreading its power-train patenting across the four technologies. The US, Tesla notwithstanding, mostly focuses on the incumbent ICE technology. The newcomers India and China are still dwarves in terms of numbers of patents, but the patents they do hold are mainly in new power-train technologies.

5 How European automotive firms tackle the EV challenge

Although they were not the first movers on EVs, European automotive firms have now become equally buoyant on the EV market. All have announced new EV models and ambitious annual EV sales targets to be achieved in the near future (Table 2).

Table 2: Automotive industry EV targets

Firms	Target dates	Sales targets
Volkswagen	2021-2025	20-30% of sales
Audi		25-30% of sales
BMW		15-25% of sales
Honda		Hybrid, plug-in hybrid, battery electric and fuel cell cars to make up two thirds of Honda's European sales by 2025
Mercedes		15-25% of sales
BYD		240k units
GM	2017-19	30k Bolts in 2017
Ford	2020-21	40% line-up, including hybrids
Volvo		1m cumulative by 2025
Tesla		1m by 2020
Toyota		1.5m
Nissan		20% of European sales
Changan		400k units cumulative
SAIC		600k units (200k domestic brand)

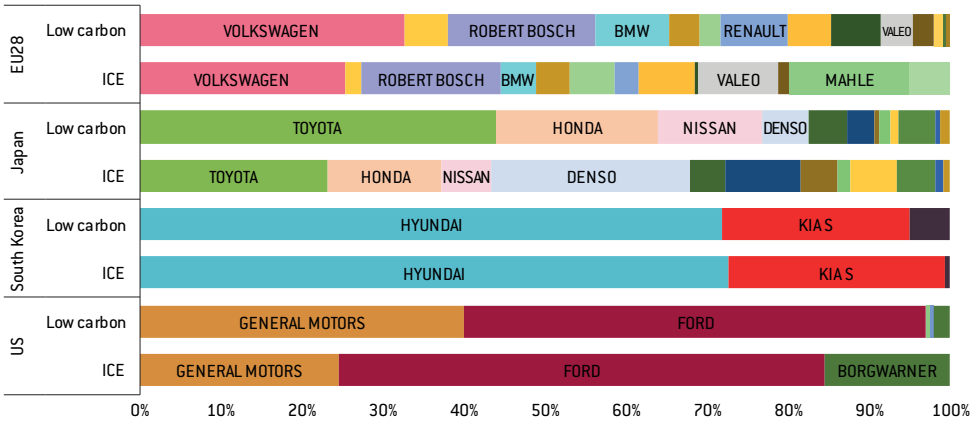
Source: Bruegel.

With most of the investment in EVs still very recent and/or in the form of announced plans, hard evidence on actual investment by EU firms in EV manufacturing is not widely available. In order to assess the commitment of EU firms to EV technology, we turn to patent statistics to assess how active EU automotive firms have been in developing EV technology compared to their international competitors and compared to their activities in improving the incumbent ICE technology.

We rely on patent data relating to automotive and parts firms included the *EU Industrial R&D Investment Scoreboard*[5]. Looking at the recent patent activity of the automotive companies, we see that different regions exhibit vastly different patent patterns.

Figure 16 shows how the overall patenting activity of countries' and regions' automotive sectors is concentrated in a few leading firms. Although challenged by new entrants, the automotive sectors have been traditionally dominated by a few major companies. That is also reflected in the patenting activity. Patenting by South Korea's automotive sector is dominated by Hyundai; in the US it is General Motors and Ford. The EU and Japan, although they have big players such as Volkswagen and Toyota, show a more distributed structure of patenting activity with more major players involved.

Figure 16: Company shares per technology per region (top 50 automotive, JRC scoreboard, 2012-2014)



Source: Bruegel based on *EU Industrial R&D Investment Scoreboard* 2016. Note: Car sector as defined by the scoreboard; category 'low carbon' comprises 'electric', 'hybrid', and 'hydrogen'; top-50 car (part) makers measured in R&D spending.

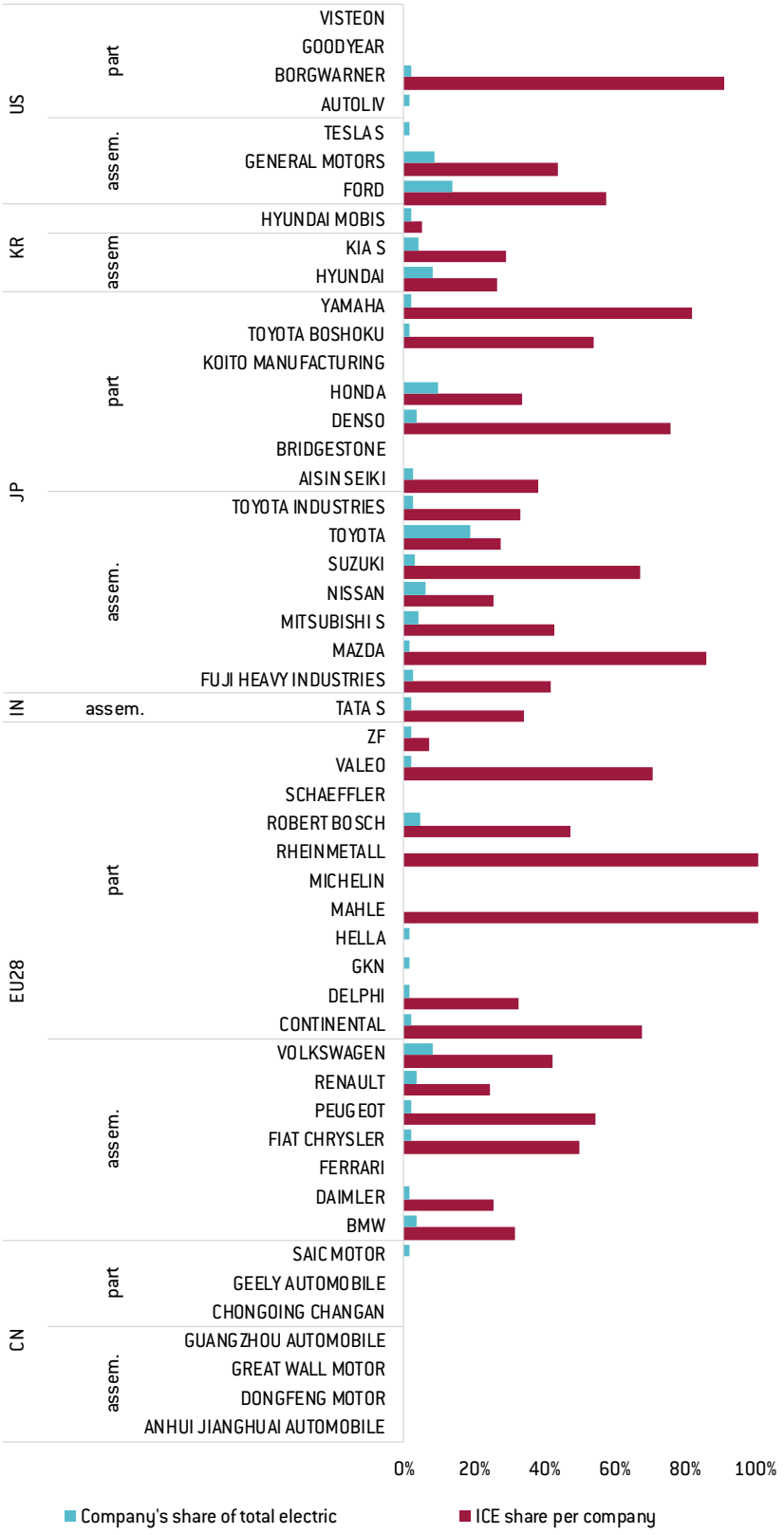
There are major differences between the patenting activities of different companies. Figure 17 shows graphically the patenting structure of automotive companies, split by assembly and part, and by country/region. As we have noted, Chinese companies exhibit an overall very low level of patenting.

Among the EU assembly companies, Renault, BMW and Volkswagen have the highest shares of electric power-train technology patents, while also having large shares of ICE patents. Overall, these EU assembly companies exhibit relatively balanced patenting activity. This contrasts with EU automotive parts companies, which exhibit a much greater degree of specialisation when it comes to power-train technologies. Some companies, such as Mahle and Rheinmetall, are active only in ICE technology patenting. Other car parts companies have higher shares of non-ICE patenting, though with low absolute numbers.

The balanced patenting activity is also true for Japanese and US automotive assemblers.

5 Note that the JRC database takes into account all kinds of patents, not only Patent Cooperation Treaty patents. To avoid double counting, we count patent families instead of patents.

Figure 17: Patenting structure of the top 50 R&D spending automotive companies (2012-14, R&D Scoreboard)



Source: Bruegel based on *EU Industrial R&D Investment Scoreboard* 2016. Note: Car sector as defined by the scoreboard; number shows patent families; *ICE share per company* shows ICE patents in total power train patents per company; Company's share of total electric shows company's share of its electric power train patents in all electric power train patents of the top-50 automotive companies.

6 Conclusions and policy recommendations

As this Policy Contribution has shown, automotive represents an important sector for the EU economy. Ensuring its long-term competitiveness is vital in order to preserve – and create – jobs. But this needs to go in hand with protection of the environment and health of its citizens. The transition to zero-emission transport and the development of alternative clean power train technologies, among which EV technology is most likely to proliferate, needs to be supported by more ambitious and broader policies both at EU and member-state levels. It is not too late for Europe to lead the global EV race, but it has to step up if it wants to remain at the frontier of automotive technology.

Europe can continue with its global leadership of the automotive sector as the next generation of automotive technologies is phased in. As this Policy Contribution has shown, European car and car parts manufacturers can rely on a large internal market, long experience in automotive manufacturing and a portfolio of R&D projects and patents that is diversified across various power-train technologies. But Europe must take on global and particularly Chinese competition. EU companies were not among the EV first movers and will have to invest more ambitiously in new EV technologies, while reducing faster their exposure to the incumbent ICE technology. Too many important companies, especially car-parts manufacturers, are still predominantly or even exclusively focused on ICE technologies. The EU lacks strong players that can capture the value from batteries for EVs.

It is for the EU automotive industry to face and ideally drive the global EV revolution and to take up pivotal positions in the EV value chain. But the proper framework conditions should be in place to warrant more ambitious investment in EV by car companies. First and foremost, there needs to be demand for EVs. Subsidies, taxation and public procurement favouring clean rather than dirty technologies should be used to stimulate demand for clean technologies in general, including EVs. On the supply side, the policy menu includes public R&D support for the next generation of clean technologies, including support for investment in the latest technologies and support for the conversion of dirty technologies into clean. Policymakers can also support clean technologies including EV, by establishing efficiency standards. Last but not least, a full range of policies can be implemented to bolster infrastructure deployment: a non-exhaustive list includes urban planning, public transport, charging stations and improving access.

Both the EU and EU member states are increasingly discussing and putting in place policies to support the deployment of EVs. However, good-practice examples of EV policies from Norway and China illustrate that piecemeal interventions will not work. What is needed is a broad policy framework, combining a multitude of demand and supply-side instruments in an ambitious long-term clean transport policy mix.

The gap in policy ambition between Europe and China is huge. The Chinese EV policy mix includes strong commitments to an electric future and coercive measures for carmakers. Europe cannot follow China in the adoption of centrally-planned industrial policy measures. However, the EU can and should do more to stimulate the transformation of its automotive industry through a more ambitious combination of several supply and demand-stimulating policy measures.

1) Targeting EU R&D funds to trigger frontier clean technologies

With more than €50 billion annually invested in R&D by the European automotive industry, we do not believe that any public R&D funding from the EU Horizon 2020 budget or any member state budget can make a substantial difference. However, the EU can improve its transport research and innovation funding. In particular, it should carefully allocate this money, targeting areas in which it can truly have leverage on private investment. This would be the most sensible way to invest the limited available resources (equivalent to 0.2 percent of the European automotive industry's total investment in research and innovation) in areas that otherwise might not receive adequate private funding. Transport-related research and

innovation funding should notably focus on next-generation early-phase technologies. This is particularly the case for batteries, such as solid-state batteries.

2) Rethinking transport taxation

Taxation is a key policy tool to switch demand to cleaner transport, fostering road transport decarbonisation. Different taxes apply throughout the transport system, from the initial purchase of a vehicle, to ownership taxes (such as annual registration taxes, company car taxation) and usage taxes (taxes on fuel, tolls, road space, parking, commuter tax deductions) (Green Fiscal Commission, 2010).

These taxes can be used to influence user decisions, and possibly also to influence the automotive industry's strategies. For instance, taxes can be differentiated on the basis of their carbon emissions. European countries still have very different transport taxation regimes. For example, only ten countries consider CO2 emissions in the composition of their vehicle registration taxes (ACEA, 2017b). Fuel cost savings – which largely arise from the different taxation of gasoline and electricity – provide EVs with an important cost advantage. Savings are significant in Norway where running an EV can cost 64 percent less than running a diesel or petrol vehicle. In Germany, by contrast, the difference is only 25 percent (Lévay *et al*, 2017).

The EU should promote a new discussion among EU countries on the future of transport taxation, as is being done in the field of digital taxation (European Council, 2017). A harmonisation of mobility taxation throughout Europe would lead to less fragmentation and more certainty for business, thus increasing the incentives to invest in production of clean (electric) vehicles in Europe.

3) Cleaning-up cars: stricter emission standards and bans on diesel and petrol cars

In December 2018, the EU reached an agreement to reduce carbon dioxide emissions from new cars by 37.5 percent by 2030 compared with 2021 (Reuters, 2018). This represents a positive step, which will contribute to spur the move towards EVs and other alternatives to diesel and petrol cars. However, this is still not sufficient to ensure a deep decarbonisation of European transport by 2050. Raising the level of ambition in this field will be crucial in the next few years.

Since 2017, a series of countries and cities across Europe have introduced bans on diesel and petrol cars. In 2017, France and the United Kingdom announced plans to ban sales of diesel and petrol cars and vans by 2040 (Petroff, 2017). Paris is developing a plan to completely phase out diesel cars by 2024 and petrol cars by 2030 (Paris, 2018). Copenhagen is discussing a proposal to ban diesel cars by 2019 (Embury-Dennis, 2017), while Madrid and Athens are considering similar proposals to be applied by 2025 (Brunsden, 2017). In Germany, after the country's highest administrative court ruled in February 2018 that diesel bans were legal, several cities have started to draw up diesel bans, such as Hamburg, Stuttgart, Frankfurt and Berlin. These plans are mainly driven by a political commitment to reduce air pollution, and are based on the expectation that the already underway shift to clean vehicles will continue to gather pace over the coming years. The more these plans will be adopted by cities across Europe, the strongest the pressure will be on the EU automotive industry to innovate and become a global player in clean vehicles.

4) EU support for member states' transition towards clean transport

The EU should encourage countries and cities to clean-up their transport systems. An 'EU Clean Transport Fund' could be established to provide dedicated financial support to countries and cities committed to transport decarbonisation (Tagliapietra and Zachmann 2018). For instance, this fund should allow cities to bid for EU money to support measures such as the deployment of alternative fuels infrastructure or to support the retraining of workers to enable them to switch from dirty to clean technology production.

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Annex 1

Power train technologies and their respective IPC patent codes

Technology	IPC patent codes
Electric	B60L 11, B60L 3, B60L 15, B60K 1, B60W 10/08, B60W 10/24, B60W 10/26
Hybrid	B60K 6, B60W 20, B60L 7/1, B60L 7/20
Hydrogen	B60W 10/28, B60L 11/18, H01M 8
Internal combustion engine (ICE)	F02B, F02D, F02F, F02M, F02N, F02P

Source: Aghion *et al* (2016).