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Reshaping the Road Ahead: Exploring Supply Chain Transformations in the EU Automobile Industry

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Reshaping the Road Ahead:

Exploring Supply Chain Transformations in the EU Automobile Industry[1]

Non-Technical Summary

This study considers some challenges in the automobile industry of the EU taking into account its relatively historical privileged international position.

It starts with an evaluation of the potential consequences arising from a global shift in the current global demand of cars, particularly towards countries like China. Assuming a continuation in the current method of car production, which relies on both internal combustion engines (ICEs) and Electric Vehicles (EVs), the shift in global demand poses adverse economic risks for the EU. This is due to the restricted use of EU supply chains to meet the current final demand for cars in the Chinese market. Next, we look at the potential macroeconomic benefits from road electrifications based on the results from the JRC GEM-E3's model. The model analyses the interactions between economy, energy and environment in the context of achieving climate neutrality by 2050. Once again, these simulations assume that the current global production networks remains unchanged.

The study then revisits this assumption by analysing the ongoing industry's transition from ICEs towards EVs and its implications for the EU industry. Although the EU is expected to emerge as the second-largest global market for EVs, this technological transition coincides with the current rise in China's share of global demand. Moreover, the electrification of transport also serves as a trigger for the ongoing transformation of the global automobile. Within this context, an examination of supply chains of EVs highlights the current dominance of China in critical value-added elements.

Despite the current strong international position of the EU's automobile industry, the findings emphasise the risks of the industry to fail to respond adequately to the ongoing technological shift. This highlights the urgent need for the EU to adapt for global trends, which includes the importance of various ongoing EU initiatives aimed at strengthening EU value chains (e.g. the European Battery Alliance, European Chips Act or the Critical Raw Material Act among others), among others. These initiatives serves as policy tools for increasing EU's competitiveness and resilience. In addition, a special role should be given to the EU's Single Market as an important source of global demand and supply, as well as to research, development, and innovation (R&D&I) as a tool for enhancing production efficiency, recycling and reducing dependency on critical inputs, including the use of alternative options.

[1] We thank Ana Norman and Matthias Weitzel for providing analytical input to the modelling section. In addition, this note has benefited from comments from colleagues of GROW CET A1 and I2–Roman Arjona, Victor Ho, Lorena Ionita, Aleksander Lazarevic, Nicholas Listl, Josefina Monteagudo, Mark Nicklas, Poalo Pasimeni, Sivia Pella.

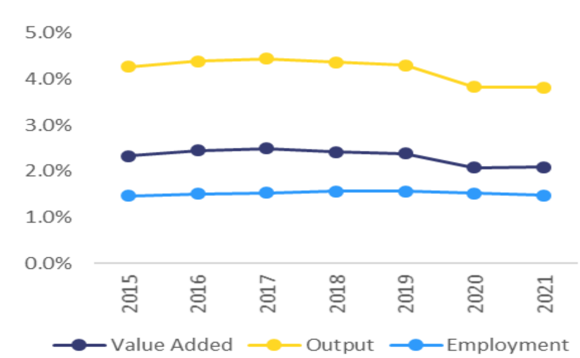
The authors remain the sole responsible for any mistake in this document.

1. The automobile industry in the EU

The automobile industry in the EU has historically shown a privileged international position. In fact, out of the ten biggest companies in the world in terms of revenues, four have their headquarters in the EU.[2] This explains that despite experiencing a declining in its contribution to the EU's GDP in recent years, the automobile industry remains a significant and direct component of the EU's economy. Graph 1 shows the share of the automobile industry in terms of value added, output and employment. A superficial look at its cost competitiveness indicates a modest decline in labour productivity. In other words, while the industry's share in terms of employment has remained relatively stable, there has been a slight decline in both value added and output over the past couple of years. However, assessing the competitiveness of this industry requires an examination of current dynamics, taking into consideration the unique characteristics of the EU's industry, its challenges and the ongoing global structural transformations.

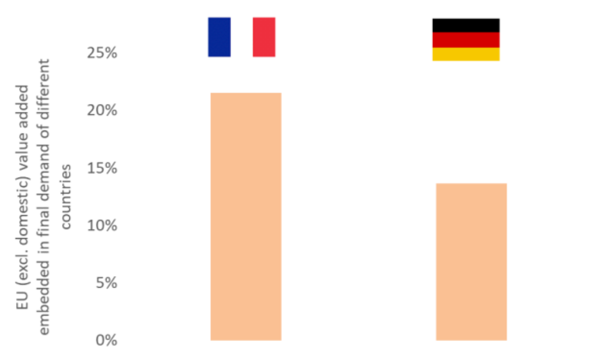
The automobile industry holds particular relevance in the context of EU competitiveness for three reasons. Firstly, it serves as a good example of the advantages derived from the EU's Single Market, given the presence of highly integrated EU's supply chains. Graph 2 supports this idea by displaying the inputs needed from other EU countries in the production of final demand for German and French-based car manufacturers. In particular, it shows that approximately 22% of the value added in the production of "French-made" cars relies on inputs generated in other EU countries, whereas in Germany, this figure accounts to 14%.

Graph 1: Value added, output and employment share in the total economy, EU-27 (%)



Source: DG GROW CET's calculations based on Eurostat (nama_10_a64) (nama_10_a64) for sector C29_C30

Graph 2: Inputs from EU countries used by Germany and France



Source: DG GROW CET's calculations based on FIGARO Input-Output tables - Year 2020. Note: Domestic inputs excluded for DE and FR.

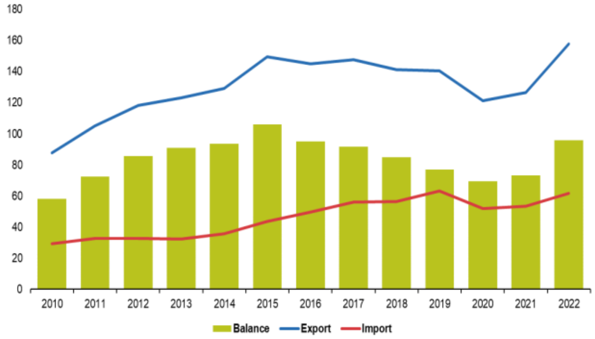
[2] This includes Volkswagen, Mercedes-Benz, BMW and Stellantis.

Secondly, the automobile industry is an economic area where the EU has consistently demonstrated a high historical competitiveness but it faces potential short-term and long-risks. To illustrate this, Graph 3 shows the exports, imports and trade balance of the industry since 2010. Notably, in terms of the sectoral trade balance, it has increased from 2010 to 2015. Since then, while exports continued exceeding significantly imports, it has shown a small decline in subsequent years, with the exception of the slight increase in 2022.[3]

Thirdly, despite the historical strong position of the EU in the car industry, the sector is undergoing short-term risks, as well as structural transformations that may potentially affect the EU's international standing. In the short-term, the industry is facing resilience challenges, as manifested in recent supply bottlenecks and disruptions. These challenges are, in part, attributable to a lack of EU's manufacturing capacity of semiconductors and other critical inputs. As shown in Graph 4, which presents the outcome of a regular company survey exercise where firms within the EU's automotive industry are asked about their recent input shortages, the resilience challenge is noticeable. From 2021 to 2023, car manufacturers of the EU reported substantial disruptions due to shortages in crucial inputs. Despite a recent decline in the proportion of companies reporting input accessibility issues, it still stands significantly above the historical average. This highlights the persistent nature of the challenge in the car industry. In addition, the industry is facing structural transformations. Graph 5 shows the annual growth rate of passenger vehicle sales across global regions, which clearly indicate a potential shift in demand pockets towards third markets, particularly China. Other structural technological transformations, which are currently affecting car producers, include the adoption of the "new" technologies such as electric vehicles (EVs). These are all important examples of technological advancements that have the potential to significantly influence the competitiveness of the EU in the automobile industry. In this context, Graph 6 shows the recent decline in the business confidence of automobile industry in the EU, which can potentially hint to the uncertainty facing this industry. Related to long-term challenges, the EU's automobile industry is undergoing substantial transformation affected by both EU and industrial policies, including emissions regulation, as well as policies implemented by our trading partners.

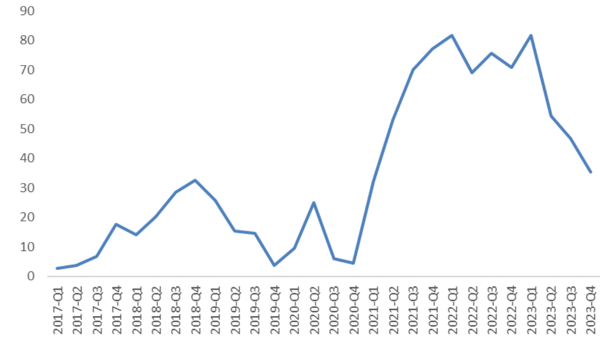
[3] A possible explanation for the significant increase in exports in 2022 compared to 2021 could be due to the difficulties faced by EU car manufacturers due to input shortages (e.g. semiconductors) could affected the resilience of EU production over the time period. See for instance the article published by the European Association of Automobile Suppliers where this problem was clearly highlighted: "*Global production shortfall of nearly 10 million vehicles in 2021 highlights urgent need for EU Chips Act - CLEPA – European Association of Automotive Suppliers*"

Graph 3: EU exports, imports and trade balance in motor cars in € billion, 2010-2022



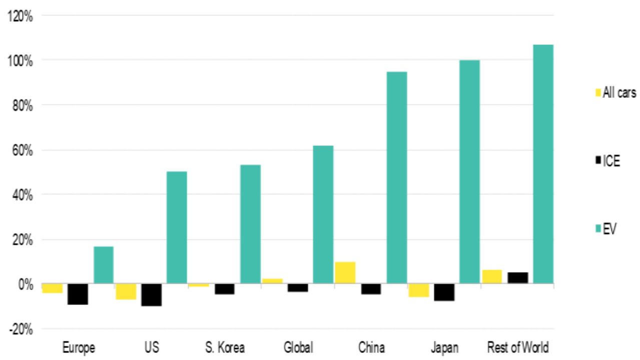
Source: DG GROW CET's elaboration based on Eurostat (DS-018995)

Graph 4: EU27 firms in the automobile industry reporting shortages of inputs (survey) (in %)



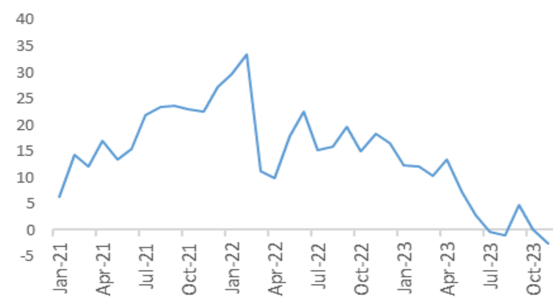
Source: DG GROW CET's calculations based on ECFIN's Business and consumer survey data

Graph 5: Annual growth rate of passenger vehicle sale, 2021 & 2022



Source: Bloomberg NEF

Graph 6: Automotive Sector Confidence Indicator (0 = neutral)



Source: DG GROW CET's calculation based on DG ECFIN confidence indicator, seasonally adjusted, for the EU-27; series INDU.EU.29.COF.BS.M.

For this reason, the analysis in the next sections will focus on the implications of the risks faced by the industry on the competitiveness of the EU. It starts by investigating the potential consequences of a shift in demand towards third countries, under the assumption that global production networks remain unchanged. Subsequently, we re-evaluate this assumption by discussing the industry's transition from combustion engine-related technologies (ICEs) to electric vehicles (EVs) and exploring its implications in terms of shifts in the global production networks.

2. Challenge and opportunities ahead with unchanged global supply chain dynamics

2.1. Ongoing global demand shift in the demand for cars

When examining the competitiveness of the automobile industry, it is essential to consider the dynamic nature of the final demand of the industry, including variations across geographical regions. Global sales of cars were declining before COVID-19, but they plummeted by 13% in 2020 due to the pandemic. Although the sales slightly recovered in 2022, the automobile industry has not returned to pre-pandemic levels. The EU is one of the regions contributing to this downward trend, which could be attributed to various factors, including market maturity evidenced by its already high density of cars per inhabitant, which impacts growth potential. Another factor contributing to this trend is the availability of alternative transportation option, particularly in relation to more robust public transport systems compared to other global regions.[4] On the other hand, the demand for cars has been steadily increasing in other regions, particularly notable in China, with forecasts indicating a sustained upward trend in the near future. As illustrated in Graph 7, demand projections indicate that market expansion is expected to continue in emerging countries such as China or India, while a decline in demand is expected for the EU and US.[5]

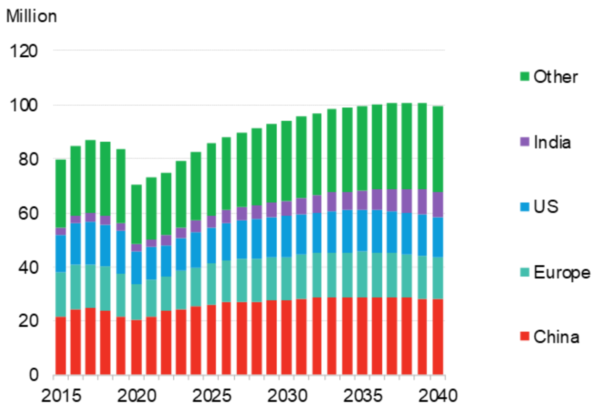
The redirection of global demand away from the EU poses a challenge for the EU's automobile industry and its economies. This is due to the greater spillover effects generated by supply chain linkages originating from the EU's final demand compared to those originating from Chinese final demand. In other words, decrease of the EU's final demand will negatively affect more EU countries due to its higher integration of supply chains across the EU.

To evaluate the value added generated in the EU from an additional euro in final demand in China compared to the EU final demand, we will rely on input-output tables capturing sectoral global value chains (GVCs). These tables provide insights into the potential production linkages in GVCs activated to satisfy the additional demand. In particular, the analysis relies on the most recent input-output tables from Eurostat, known as FIGARO. Graph 8 takes into account both direct and indirect contributions to final demand of the EU and China. Specifically, it considers EU inputs contributing to domestic demand and encompasses EU inputs embedded in cars exported to

[4] Mulalic et al. (2015)
[5] A potential reason for this is that the EU and US are mature markets with a high share of cars per inhabitant, while countries such as China and India have still high market growth potential.

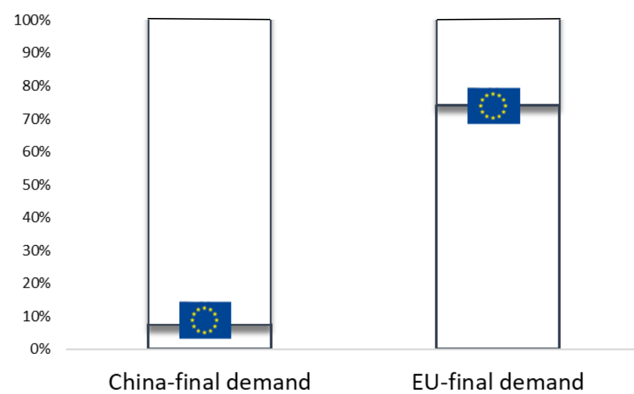
EU/China consumers, even if those cars originated in third countries.[6] Our estimates suggest that the EU contributes approximately to 7.5% to the value added generated by the final demand of Chinese consumers. This contribution includes both direct exports from the EU to China and indirect inputs, which extend to components embedded in Chinese domestic car sales and third-country exports to China, involving partners like the US or India. This contrast to the 74% of value added generated within the EU from the final demand of EU consumers.

Graph 7: Global annual passenger vehicle sales outlook by market



Source: Bloomberg BNEF. Note: 'Other' includes Japan, South Korea, Australia, Southeast Asia, Canada and other Rest of World.

Graph 8: The EU's contribution (in value added) to the final demand for cars in both the EU and China (%)



Source: DG GROW CET's calculations based on FIGARO Input-Output tables, Year 2020

The preceding analysis suggests that the automobile industry in the EU could face a decline in competitiveness if a significant portion of global final demand shifts to third countries, primarily due to its relatively lower involvement in the production serving the final demand in those markets. However, it is crucial to note that this assessment relies on the assumption of a stable production network of the car industry, composed by the production of internal combustion engines (ICEs) and Electric Vehicles (EVs). This assumption relies on the idea that global car producers will continue to use the same inputs from the same sources. In other words, it assumes that current car producers will maintain the identical input mix for satisfying the additional global demand, employing what is technically known as Leontief production functions. However, the ongoing transformation in the automobile industry, especially the shift towards electric vehicles, suggests the potential for substantial changes in the production function of car manufacturers. This evolution is likely to result in manufacturers seeking different inputs, thereby altering the graphical

[6] See Los et al. (2015), Arto et al. (2019) and Connell et al. (2020) for more details on the methodology.

composition of its production. This transition has the potential to affect the EU's sectoral competitiveness, especially if car manufacturers in the EU incorporate fewer "made in the EU" inputs into their production processes.

2.2. Macroeconomic impact of road electrification

Prior to evaluating the supply chain consequences of the transition towards EVs, this section centres on evaluating the macroeconomic impacts of electrifying road transport. For the purpose of this analysis, road transport electrification is considered within the current framework of global production network of cars, assuming no substantial alternations, particularly in trade patterns. In essence, this assumes that the EU can sustain the same level of value-added production in the future of manufacturing cars as it presently achieves, which currently encompasses the mix of ICEs and EVs.

In order to evaluate the economic effect of this transformation, which extends beyond the boundaries of the vehicle-manufacturing industry, this note uses the JRC GEM-E3's model. This analysis evaluates the macroeconomic impact of road transport electrification in the EU within the context of climate neutrality, i.e. developing scenarios before and after the introduction of the Fit-for-55 (FF55) package.[7] This analysis not only explores the transformation within the automobile industry, but also evaluates the broader economic consequences, providing insights into how the shift towards EVs reverberates across the entire economy and labour market. According to the JRC model, a progressive adoption of EVs by households and firms in the EU up to 2050 has the potential to yield a positive impact on the EU GDP of approximately 0.5% by 2050 compared to a baseline. The baseline reflects climate and energy policies prior the Fit-for-55 (FF55) package. These benefits primarily derives from efficiency gains, which reflect a decrease in battery cost following the acceleration in the adoption of technology (learning by doing), as depicted in Graph 2 in the Annex. Moreover, not only EVs tend to have a lower maintenance costs than comparable conventional vehicles, they also save oil consumption and these are more efficient than combustion vehicles[8]. The Annex also outlines expected employment effects. In particular, Graph

[7] The results are based a case study of the automotive industry carried out by JRC for DG GROW. The study uses the JRC-GEM-E3 model in the context of increased deployment of EVs in the EU in line with recent policy plans for climate actions. As explained in the text, GEM-E3 model develops baseline and policy scenarios that reflects the changes of the climate policy using the Fit-for-55 (FF55) package's MIX scenario proposed in July 2021. For more details, please on the assumptions and explanation these scenarios see Appendix 1.

[8] The estimated reduction costs depended on the type of vehicles considered, their sizes, mileages covered, geographical locations, technical and mechanical characteristics. For more details on the literature and the assumption included in the model based on this literature, see Annex 1.

3 of the Annex shows the changes in absolute employment of an increase in the deployment of EVs across sectors. As expected, electric supply sector will have a positive effect, whereas the fuel sector are projected to bear the most significant adverse effect. In terms of the occupation group, the largest positive impact in terms of labour market is not surprisingly associated to the manufacturing of vehicles. Graph 4 of the Annex illustrates the gain of a 0.16% increase in plant and machine operators and assemblers.[9]

However, as previously mentioned, this analysis does not take into account trade patterns dynamics and implications linked to such a transformation. Such as a shift towards EVs could indeed add additional challenges for the industry, a topic further explored in the next section.

3. Rise of Electric Vehicles (EVs)

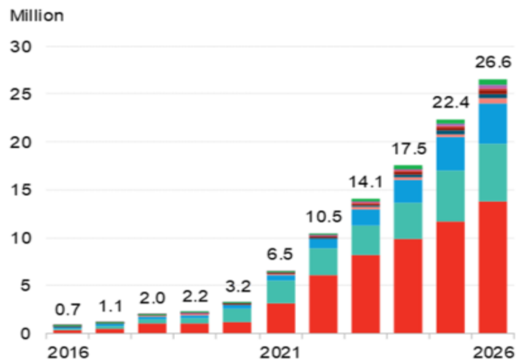
3.1. EVs: Evidence of the ongoing structural shift

The previous sections have discussed the challenges arising from a shift in car demand towards non-EU countries and the potential macroeconomic benefits arising from a road electrification of the EU. This section turns to the ongoing historical structural transformation of the industry in terms of deployment EVs and the implications that it could have in terms of global supply chains. Graph 9 shows that global sales of EVs are set to experience a substantial increase in the coming years, projecting an increase from 10.5 million in 2022 to nearly 27 million in 2026. In terms of market shares, Graph 10 shows that the global share of EVs in new passenger vehicles is expected to increase from 14% in 2022 to 30% in 2026. Furthermore, specific regional forecasts indicate that in key markets such as China and the European region,[10] the adoption of EV is expected to reach 52% and 42%, respectively. In the US, on the other hand, significant efforts from the Inflation Reduction Act (IRA) are foreseen to push EVs to constitute nearly 28% of passenger vehicle sales by 2026, a significant increase from the 7.6% observed in 2022. Consequently, the demand for EVs follows a somehow similar pattern to the global car market trends, shifting towards Asian markets, particularly in China. However, contrary to overall car demand, where the European region's second position is challenged by the rest of the word, in EVs, Europe maintains a notable second position, surpassing competitors such as the US and all

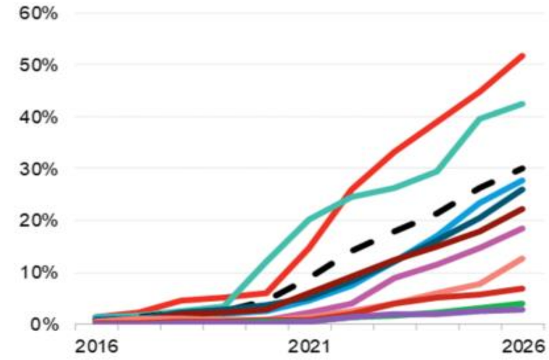
[9] As with any general equilibrium model, the results presented have to be interpreted as indicative trends, being based on a number of assumptions on technological transformation, including decarbonisation-related innovation.
[10] Note that in this chart, Europe includes the EU, the UK and European Free Trade Association (EFTA) countries.

other countries combined (excluding China and the US).[11] Analysing the potential global beneficiaries and those facing challenges in this transformation provides valuable insights into the future competitiveness of the automobile industry.[12]

Graph 9: Global near-term passenger EV sales outlook by market



Graph 10: Global EVs share of new passenger vehicle by market (%)



Note: Europe includes the EU, the UK and European Free Trade Association (EFTA) countries. EV includes battery electric EVs and plug-in hybrid EVs.
Source: Bloomberg BNEF, 2023

3.2. EVs: Impact on the automobile supply chain

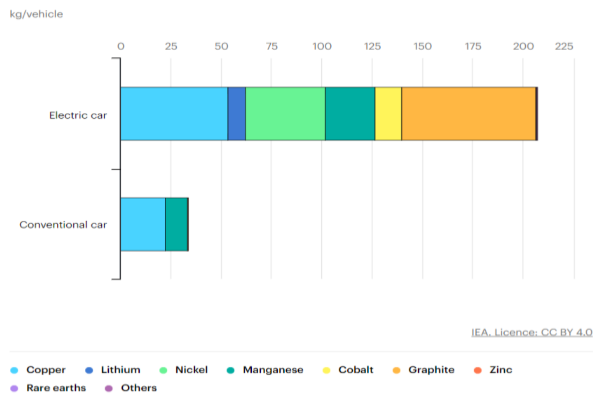
A previously mentioned, EVs are experience substantial growth in sales in key markets. For this reason, there is a need to shift attention towards global supply chain considerations, evaluating the potential impacts on the reallocation of required inputs. In fact, comparing EVs with ICEs cars result in a noticeable change in the mineral demand composition. In this context, Graph 11 illustrates that a standard EV requires six times the mineral inputs compared to ICEs.[13] This shows that a transition towards EVs will require a significant change in the raw materials needed by car manufacturers.

A clear illustration of the scale of this transformation is evident in the minerals and metals essential for manufacturing EV batteries, constituting up to 40% of the total value of electric vehicles (IEA, 2022b).[14] Notably, the demand for automobile lithium-ion (Li-ion) batteries has surged to approximately 550 GWh in 2022, marking a threefold increase compared to 2020 levels. Graph 12 shows China as the primary driver behind this increase, with their demand for EV batteries

[11] Bloomberg BNEF (2023).
[12] The EV market reveals significant variations among EU countries. See Annex 1 for more details.
[13] IEA (2022a)
[14] IEA (2022b)

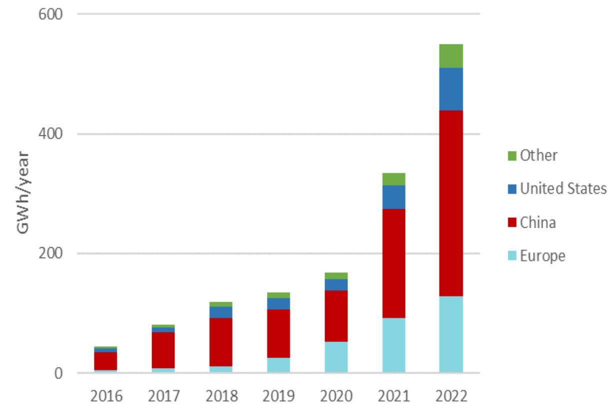
having more than tripled over the same period. On the other hand, in the European region and to lesser extent in the US, although demand remains notably lower than China, there has been a robust increase since 2019.

Graph 11: Minerals used in electric cars compared to conventional cars



Source: IEA, 2022

Graph 12: Battery demand by region 2016-2022



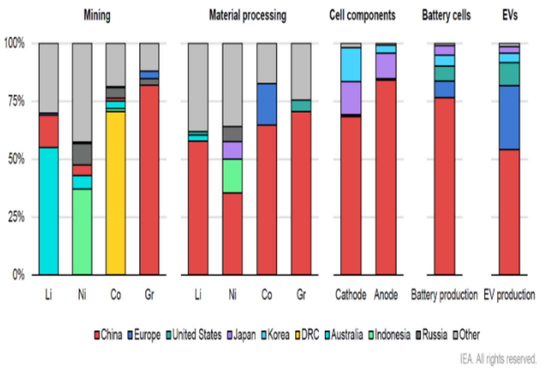
Source: IEA, 2023. Note that in the IEA report, Europe includes EU27 countries, Iceland, Israel, Norway, Switzerland, Turkey and the UK.

The subsequent logical question arises: Who is responsible for the production of EV batteries? Looking at the midstream and downstream of EV battery supply chain, from material processing to final production, we observe a high concentration in China.[15] The country processes and refines more than half of the capacity of lithium, cobalt, and graphite. Additionally, China is the primary location for the production capacity of key battery components, including cathodes and anodes. As observed in Graph 13, the country also controls three-quarters of the global capacity of the cell battery production. In contrast, while the EU accounts for around 25% of EV production, it has a much smaller involvement in the production of its inputs.

Zooming into the upstream segment of the EV battery supply chain introduces a more complex picture. Despite China contributing only 3% and 11% to the global mine capacity for cobalt and lithium, respectively, the ownership dynamics present a different perspective.[16] Graph 14 illustrates that, in terms of ownership, Chinese companies have acquired or presently possess substantial stakes in companies holding mining rights in crucial supply regions. This includes the Democratic Republic of the Congo for cobalt and South America and Australia for lithium.[17]

[15] IEA (2022b)
[16] JRC (2022)
[17] The 2022 JRC report highlights China's strategy to secure row materials by investing in mining projects worldwide

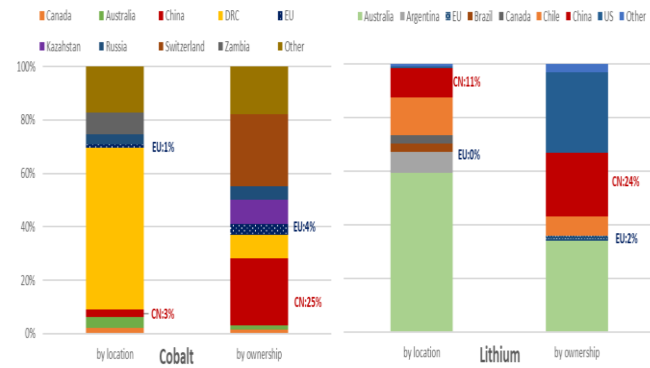
Graph 13: Geographical distribution of the global EV battery supply chain, 2022



Note: Li = lithium; Ni = nickel; Co = cobalt; Gr = graphite; DRC = Democratic Republic of Congo. Geographical breakdown refers to the country where the production occurs. Note that in the IEA report, Europe includes EU27 countries, Iceland, Israel, Noway, Switzerland, Turkiye and the UK.

Source: : IEA, 2022

Graph 14: Cobalt and lithium mine capacity in 2020



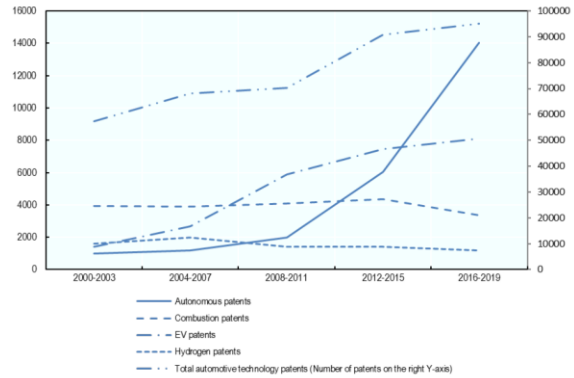
Source: JRC, 2022

The figures above underscores the implications for global supply chains and the source of generated value if a shift towards EVs were to occur, particularly considering China's important role in various stages of the global supply chain for EVs. For this reason, if the EU were to maintain its competitiveness in the supply chain of the industry, there is a need to enhance its participation in the different stages of the supply chain. If this is not possible due to natural endowment constraints, strategies such as circularity/recycling or reducing supply chain risks through further diversification should be taken into account. Simultaneously, there is a pressing need for the EU to maintain its commitment to investing in research, development, and innovation (R&D&I). This strategic focus can enhance production efficiency, recycling and reduce dependence on critical materials through the incorporation of alternative inputs. A recent modelling analysis by the OECD[18] suggests that boosting green fiscal spending could result in a significant decrease in unit production costs of critical green products. For example, as for EV batteries, this decrease in unit cost is projected to be around 40% in North America and 35% in the EU by 2035. More broadly, there has been a notable increase in global innovation concerning technologies in the field of EVs. Graph 15 shows a consistent upward trajectory in the annual patent applications for electric vehicle EV-related technologies as since 2017, these applications have surpassed those for combustion engine-related technologies. Graph 16 shows that in terms of the origin of these patents, Japan, US, Germany and Korea have filed the highest number of patents between 2016

[18] Aulie, F. et al. (2023)

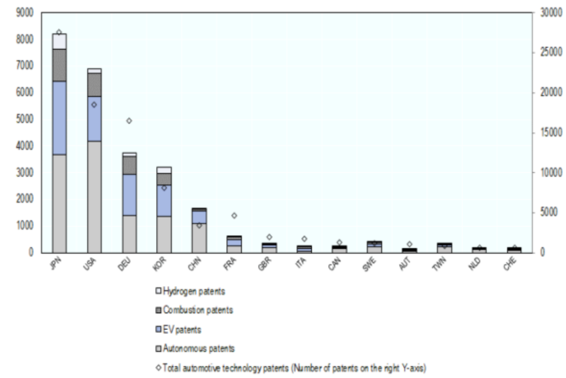
and 2019. It is important to highlight that in the EU only Germany still holds a slight hedge in the number of EV patents.[19]

Graph 15: Patent filings in total automotive technologies, by technology 2016-2019



Source: OECD, 2023

Graph 16: Patent filings in total automotive technologies, by country and technology 2016-2019



Source: OECD, 2023

4. Conclusion

This study considers some challenges in the automobile industry of the EU taking into account its relatively historical privileged international position.

Our analysis first examines the potential effects of a shift in car demand toward third countries, particularly China, under the assumption that global production networks remain unchanged. We observed that a reduction in the EU's share of global final demand at the expense of China may have a more pronounced impact on EU countries. This is primary due to the limited use of EU supply chains in meeting Chinese final demand as opposed to fulfilling EU's final demand. Next, we looked at the potential macroeconomic benefits from road electrifications.

Subsequently, the assumption regarding the continuity of global production networks was relaxed by discussing the ongoing transition in the automobile industry's business model away from ICEs technologies towards EVs.

Our main observation was that the demand for EVs is observing a shifting towards Asian markets, particularly China, with Europe coming in a significant second place. Sequentially, we investigated the supply chains of key components in EVs to highlight the extent to which China exerts dominance over crucial value-added inputs. The observed dominant position of China in important

[19] OECD (2023)

segments of the supply chain of EVs highlights the importance for the EU car manufacturing and its domestic supply chains to adapt in order to maintain its current level of global competitiveness. In this respect, ongoing policies aiming at strengthening the EU's position in the automobile supply chains (e.g. the European Battery Alliance, European Chips Act, the Critical Raw Material Act, Net Zero Industry Act among others) can have an important role to play. In parallel, EU policy in research, development, and innovation (R&D&I) is key not only to foster product innovation but also to enhance production efficiency and increase resilience by reduce the foreign dependency on critical inputs (including raw materials) used for EVs by incorporating alternative options.

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Annex: Projected macroeconomic and sectoral impacts of deployment of electric vehicles

This Annex informs on the main scenarios, assumptions and analytic results stemming from a version of JRC-GEM-E3 model that JRC has developed in collaboration with DG GROW.[20] This version explicitly represents the manufacturing of electric vehicles and is able to assess the macroeconomic and sectoral effects (e.g. GDP, employment) triggered by climate policies, such as the Fit for 55 package, that stimulate the market share of EVs in the EU over the next decade. Within this policy context, the model looks specifically at the effects from only changes in the deployment of electric vehicles to decarbonize transport and assumes not changes in trade patterns between traditional combustion vehicles and EV vehicles.

Model and scenarios

JRC-GEM-E3 is an applied general equilibrium model that covers the interactions between the Economy, the Energy system and the Environment. In the context of the deployment of the EVs in the EU, the model employs the latest GTAP database (version 10, released 2019) and produces results in terms of shifting vehicle production in line with a climate neutrality scenario against a baseline scenario. The two scenarios are summarised in the table below.

Table 1. Overview of the scenarios

Scenarios	Major Assumptions
Baseline	This scenario reflects the climate and energy policies integrated in GECO 2021[21], prior the Fit-for-55 (FF55) package introduction. Based on PRIMES reference, this scenario envisions that by 2050, 39 % of the private and 28% of the commercial road transport fleet are electric (See graph 1)
1.5C Pathway	This scenario reflects the changes of the climate policy using the Fit-for-55 (FF55) package's MIX scenario proposed in July 2021[22] that affect land transport. In particular, this scenario shifts purchases of households and firms towards electric vehicles and adjusts the fuel mix in line with shift in the vehicle stock. It does not impose the effect of the Fit for 55 package to other sectors of the economy, such as decarbonization in buildings, the power sector, etc. No changes are made in the Rest of the World compared to the Baseline. This scenario imposes a stronger penetration of EVs from 2020 by households and firms. EVs reach 83% of private and 63% of the commercial road transport fleet (See graph 1)

[20] The model updates a version of the JRC-GEM-E3 used to carry out a case study evaluating the macro-economic impact of different electrification scenarios of road transport in the EU, see, Tamba, M., Krause, J., Weitzel, M., Ioan, R., Duboz, L., Grosso, M., & Vandyck, T. (2022). Economy-wide impacts of road transport electrification in the EU. *Technological forecasting and social change*, 182, 121803.
[21] For the EU, this scenario corresponds to the EU Reference Scenario 2020, which formed the basis of the analysis of the 2030 Climate Target Plan and the Fit for 55 policy package to deliver on the 55% reduction ambition; it was also used as a basis for the analysis of RePowerEU. For see https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en
[22] The MIX scenario is described in SWD(2021) 601; for more details of the JRC-GEM-E3 implementation, see Annex 4 of SWD(2021) 643.

Macroeconomic impacts

The model focuses on the gradual increase in purchases of EVs by households and firms aligning with a 1.5C vehicle stock scenario trajectory. If electric vehicles were keeping their cost markup relative to conventional vehicles, switching to electric vehicles would be expensive and lead to a loss in GDP (stock effect). However, rapid technological development suggests falling battery costs could result in price parity between conventional and electric vehicles as early as 2025.[23] For the analysis we impose a cost reduction trajectory for batteries in EVs consistent with the learning-by-doing assumed in the EU's Long-term Climate strategy[24] (learning effect), offsetting the stock effect once electric vehicles are cost competitive with conventional vehicles. In addition, electric vehicles have lower maintenance costs than comparable conventional vehicles, although literature estimates range from a minimum reduction of 16%[25] to a maximum of 75%[26] (Lee et al., 2013), depending on the type of vehicles considered, their sizes, mileages covered, geographical locations, technical and mechanical characteristics. In the model, an average value of 30 % of maintenance cost reduction of BEV compared to conventional vehicles is used, applied as a reduced expenditure on maintenance services by owners of BEVs in both passenger and freight transport. This increases GDP by reducing operational costs, freeing up resources for investments or consumption elsewhere. Finally, electric vehicles save oil consumption and are more efficient than combustion vehicles, considering this (fuel effect) leads also to a positive effect on GDP. The total effect of these channels is positive. The positive impact on the EU GDP reaches approximately 0.5% by 2050 compared to the baseline, as Graph 2 depicts.

Policies aimed at reducing greenhouse gas (GHG) emissions and promoting the deployment of electric vehicles (EVs) can have the potential for a significant impact on the structure of the EU economy. Graph 3 highlights the changes in absolute employment of an increase deployment of EVs under the 1.5C pathways scenario across sectors. As expected, a positive effect will be seen in the electric supply sector.

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[23] see Bloomberg New Energy Finance –BNEF-, 2021 New Energy Outlook 2020, Executive Summary https://about.bnef.com/new-energy-outlook/BNEF 2021; UBS, 2017 UBS Evidence Lab Electric Car Teardown –Disruption Ahead? UBS Global Research Report https://neo.ubs.com/shared/d1wkuDlEbYPjF/

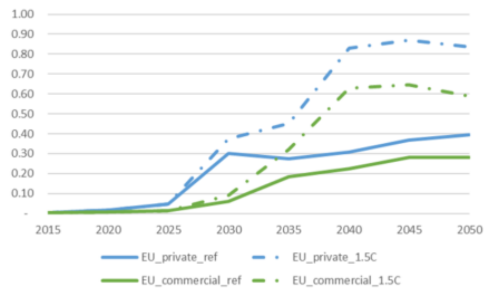
[24] European Commission, 2018 In-depth analysis in support of the commission communication COM(2018)773; a clean planet for all A European Long-term Strategic Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy, https://ec.europa.eu/clima/sites/default/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

[25] Gnann, n.d.T., Plötz, P ., Funke, S., Wietschel, M. What is the market potential of electric vehicles as commercial passenger cars? A case study from Germany, Fraunhofer ISI , Working Paper Sustainability and Innovation No. S 14/2014, n.d. Available at: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2014/WP14-2014_Gnann-Ploetz-Funke-Wietschel_commercial_EVs.pdf.

[26] Lee, D., Thomas, V., Brown, M. 2013. Electric urban delivery trucks: energy use, greenhouse gas emissions, and cost-effectiveness. Environ. Sci. Technol., 47 (14), pp. 8022-8030

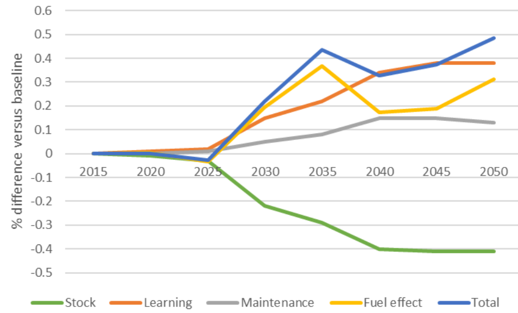
Nevertheless, the occupation group experiencing the largest positive impact in terms of employment is not surprisingly associated to the manufacturing of vehicles, as Graph 4 illustrates, with a 0.16% increase in plant and machine operators and assemblers.

Graph 1: Share of private and commercial EV vehicle sales in the baseline and in the 1.5C scenario



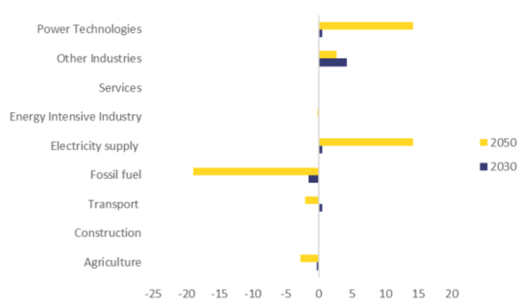
Source: Own calculations based on JRC-GEM-E3

Graph 2: GDP impact of land transport transition under the 1.5C scenario compared to the baseline scenario



Source: Own calculations based on JRC-GEM-E3.

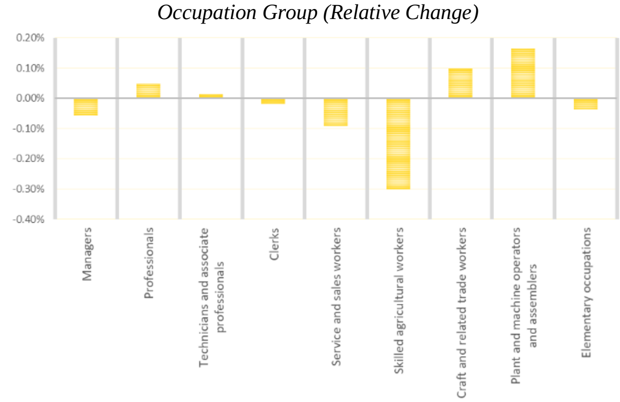
Graph 3: Impact on Employment of land transport transition under the 1.5C scenario compared to the baseline scenario



Source: Own calculations based on JRC-GEM-E3

Graph 4: Employment effect by occupation

Difference in employment vs. Baseline in 2030, Occupation Group (Relative Change)



Source: Own calculations based on JRC-GEM-E3

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