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THE WORLD TO COME: KEY CHALLENGES FOR THE AUTOMOTIVE INDUSTRY*

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The automotive industry is going through a paradigm change that will affect the entire supply chain, and have the potential to redraw the boundaries of the sector, redefine the key players and sourcing practices, and affect the relative advantage of countries and regions, reshaping existing industrial geographies. We address the issue of the reorganisation of the global value chains in the face of various challenges: new, large markets opening up, and new, aggressive competitors emerging; an increasingly unpredictable global geopolitical context, translating into the forging and undoing of trade agreements; the reorganisation in value chains, induced by new digital technologies; and the redefinition of what a "car" is, determined by electrification, autonomous driving, and new mobility. These simultaneous changes impact upon the geographical location of the industry, the distribution of power within the value chains and between incumbents and new players entering the industry (from energy firms and power utilities to battery producers and big

L'industria automobilistica sta attraversando un cambiamento di paradigma che coinvolgerà l'intera filiera produttiva e che potenzialmente ridefinirà i confini del settore, riplasmerà gli attori principali e le prassi relative all'approvvigionamento, e avrà un impatto significativo sul vantaggio relativo di Paesi e regioni, modificando profondamente le geografie industriali esistenti. Tratteremo la questione della riorganizzazione delle catene globali del valore alla luce delle sfide che si presentano: nuovi mercati di grandi dimensioni e nuovi concorrenti agguerriti; un contesto geopolitico globale sempre più imprevedibile, che si traduce nella firma e nello scioglimento di accordi commerciali; la riorganizzazione delle catene del valore indotta dalle nuove tecnologie digitali; la ridefinizione del concetto di "automobile", dettata dai veicoli elettrici, dai veicoli a guida autonoma e dalle nuove forme di mobilità. Questi cambiamenti, che avvengono simultaneamente, hanno un impatto sulla collocazione geografica dell'industria, sulla ripartizione dei poteri all'interno delle catene del valore e tra, da un lato, gli attori tradizionali già

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tech monopolists), with obvious consequences for the distribution of production and employment across countries and within manufacturing and service sectors.

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presenti all'interno del settore industriale in analisi e, dall'altro, i nuovi entranti (che includono le aziende del settore energetico, i fornitori di energia, i produttori di batterie e i grandi monopolisti dell'industria tecnologica), con conseguenze ovvie in termini di ripartizione della produzione e dell'occupazione tra i vari Paesi e all'interno dei settori manifatturiero e dei servizi.

Parole chiave: industria automobilistica, catene globali del valore, transizione verde e digitale, nuove forme di concorrenza.

1. Introduction

The automotive industry is undergoing a radical transformation. New social, technological, environmental, and geopolitical challenges are redefining the characteristics of a saturated market in the Western countries, opening new scenarios while offering opportunities for the entry of new players. The transformations taking place are bound to change the global structure of automotive production. Competition is no longer just between the traditional players, but extends beyond the automotive sector – to include innovation in batteries, software, connection, and mobility – and attracting new investors from outside the industry – tech companies, venture capital, and private equity players. The rise of new competitors from the emerging economies and would-be entrants from other sectors, competing in mastering the new digital and software technologies, threatens the established structure of the industry.

The pandemic has led to a spectacular acceleration in this process of change, while heightening uncertainty about future developments. The legacy (i.e. established) European, US, and Japanese carmakers have been slow in responding to the challenges posed by electric vehicles (EVs) and autonomous driving vehicles (AVs), though finally taking up the challenge, and speeding up the production of electric and hybrid vehicles, to comply with ever-stricter emissions regulation, take advantage of the new market opened by government EV subsidies, and, above all, catch up with new, challenging competitors in their own markets. The current automotive transition is likely to open the way to a radical change in the comparative advantage of nations, with important consequences for the quantity and quality of employment. This is why the Governments of the leading countries are joining the race, wielding carrots and sticks in support of their industries to encourage risk-taking and investment in research and innovation, step up EV production while providing for the necessary infrastructure, and guarantee their companies a place in the new industry. In turn, in defining their strategies, old and new players must take into account geopolitical factors – such as adversarial US-China relations and a tougher US stance vis-à-vis Canada and Mexico within the just signed USMCA (USA-Mexico-Canada) Treaty, as well as its European "allies" – and the struggle to secure new key resources and materials, which add to technological factors in aggravating uncertainty.

With the outbreak of the war in Ukraine, the considerations made here on the implications of geopolitical risks for the automotive sector are only reinforced, and energy issues together with an outlook of recession in the global economy create further uncertainty with regard to the development path of the automotive industry.

In this paper, we address the issue of the reorganisation of global value chains in the face of these various challenges, namely: the opening of new, large markets and the emergence of new, aggressive competitors; an increasingly unpredictable global geopolitical context translating into the forging and undoing of trade agreements; the reorganisation in value chains induced by new digital technologies and the disruption of supply chains caused by the pandemic; finally, the redefinition of what a "car" is, determined by electrification, autonomous driving, and new mobility. These simultaneous changes impact upon the geographical location of the industry, the distribution of power within the value chains and between incumbents and new players entering the industry (from energy firms and power utilities to battery producers and big tech monopolists), with obvious consequences for the distribution of production and employment across countries and within manufacturing and service sectors. Section 2 describes the *status quo ante*, achieved in the course of the first great transition ushered in by the technological and organisational innovations of the 1980s and 1990s, which led to the creation of a hierarchical regionalisation of production and trade. Section 3 outlines the main factors challenging the *status quo*, and Section 4 focuses on winners and losers with respect to labour and peripheries. Section 5 offers some preliminary reflections on the world to come.

2. The creation of a hierarchical regionalisation of production and trade

The automotive industry is highly concentrated: in 2018, the top 20 automakers employed approximately 75% of all employees working at car manufacturers worldwide, and contributed with about 88% of the global vehicle production volume (Hoeft, 2020). It is also one of the most globalised industries: historically highly clustered in core areas since the late 20th century, it embraced global sourcing, with peripheral areas taking on more prominence. The reorganisation of the automotive supplier industry was made possible by new transportation technologies and logistical systems and by technological and organisational changes that significantly reduced the number of suppliers, and organised the remaining ones into tiers. The requirements of just-in-time production, along with local content and the request by original equipment manufacturers (OEMs) to their main suppliers to be followed in their new locations (the so-called "follow sourcing"), led to the increased clustering of especially Tier-1 suppliers around assembly plants (Sturgeon, Van Biesebroeck and Gereffi, 2008; Pavlínek, 2018). Global sourcing was triggered by the profit-seeking strategies of firms exploiting countries' differences in levels of development and factor costs (Harvey, 2014). The need to produce where you sell added to the production diaspora. The geographic structure of the automotive industry is now based on the presence of large assemblers and leading (global) suppliers in all major markets, organised in functionally integrated macro-regional production networks. The competitive process results in the dynamic nature of nations' position within automotive production networks, with production moving between core, semi-periphery, and integrated periphery.

Core and peripheries

In the first wave of restructuring that started in the 1990s, the big carmakers exploited the strategies of peripheral countries' Governments aiming to attract foreign direct investment (FDI) through cheap labour and fiscal concessions, while taking advantage of their geographic proximity to large markets and of their participation in regional trade

agreements. The main producers of components (the Tier-1 suppliers) followed their customers in their delocalisation. The end result was a highly globalised industry, organised in macro-regional clusters of production networks, such as USA-Canada-Mexico in North America, Germany-southern and eastern European countries in Europe, Japan-China-Korea and East Asian countries in Asia, and Brazil-Argentina in Latin America.

The resulting hierarchical regionalisation of production and trade has been investigated within the theoretical framework of core-periphery relations. The periphery is distinguished between two sub-categories: the integrated periphery and the semi-periphery. Integrated peripheries reflect the rise of the global industry, with centrally developed platforms using a standard set of materials and components worldwide (Smitka and Warrian, 2016). Mexico and the CEE (central and eastern European) countries respond to most of the characteristics of integrated peripheries, as identified by Pavlínek (2018): smaller domestic markets, export-oriented assembly of inexpensive mass-market models and components, foreign ownership and control of assembly and Tier-1s, low labour costs, scant strategic functions, and weak activation of domestic suppliers.

A high degree of foreign control of the automotive industry by the core-based multinational companies (OEMs) is a feature also shared by semi-peripheries, denoting countries that lack (or have lost) a domestically headquartered carmaker. Following Mordue and Sweeney's (2020) definition, unlike the integrated peripheries, semi-peripheral automotive countries are home to a well-educated, relatively high-cost workforce and headquarters location of some large automotive parts suppliers. They also tend to retain significant (though declining) levels of automotive production, but have proven incapable of attracting significant mandates for automotive R&D. In fact, empirical studies on the automotive industry found that R&D tends to concentrate in locations proximate to corporate headquarters (Mordue and Sweeney, 2017). Thus, while survival of their value chains relies basically on the ability to move to high-value, advanced-research, and innovation products, their lack of many regional assets endogenous to the core, such as a domestically headquartered automaker, and the clustering of R&D and managerial functions, have strong implications for strategic decision making and technological, know-how, and managerial dependency. Moreover, with assembly plants moving offshore, even Tier-1s will struggle to stay, and their relocation will threaten the collapse of the entire value chain. With the globalisation of the industry, the competitive advantage of semi-peripheries has diminished throughout the 21st century.

This classification, useful for offering a fresco of the regional recomposition of production, structured in relations of integration and dependence, should not obscure the differences between the various clusters of cores and integrated peripheries. Our reconstruction of the developments in the Mexican automotive industry (Carreto Sanginés, Russo and Simonazzi, 2021) has highlighted how differences in the strategies of firms and Governments in the core affect the qualities of the relations with their integrated peripheries, as well as their future development. Comparing two main clusters will illustrate the point. In the case of the North American cluster, the core has been systematically lagging behind the main transformations pioneered by its competitors. In the 1970s-1980s, US companies had to respond to the increasing foreign (mainly Japanese) competition in their own, hitherto protected, market. The Japanese threat threw the US automotive industry into panic, and triggered the US Government's response. Protection of the domestic market from import penetration attracted FDI. Japanese and European firms brought new technology into US auto assembly, including extensive use of robots and just-in-time inventories (Hufbauer and

Jung, 2021). The transplants also instructed parts suppliers on better manufacturing and quality control methods, and parts production was upgraded. Faced with the risk of losing control of their home market to foreign manufacturers, US carmakers resorted, among other strategies, to offshoring of labour-intensive operations, relocation in the southern non-unionised States in the USA, and delocalisation of assembly plants to Mexico, even before the North American Free Trade Agreement (NAFTA) was signed.

In the case of the German cluster, since the 1990s, following the fall of the iron curtain first, and then the eastern enlargement of the EU, massive relocation of production eastwards has allowed the main European OEMs, and especially the German ones, to take advantage of the creation of the Common Market and to meet the challenges represented by Japanese and, later on, Korean transplants (Brincks *et al.*, 2018). Unlike in the USA, however, these processes contributed to reinforcing the competitive position of the lead country and its "national champions". In fact, compared to the USA, German companies offshored a higher share of components and small cars, while retaining at home a higher share of production and assembly of premium cars (Simonazzi, Carreto-Sanginés and Russo, 2020). Thus, although production facilities in Europe and North America have been increasingly located in peripheral regions – central Mexico in North America, and former Communist countries in Europe –, the consequences on production and employment in the core countries have differed substantially.

Cheap labour, geographic proximity to large markets, membership in regional trade agreements, and investment incentives lie behind the growth of an automotive industry in integrated peripheries, as well as the simultaneous restructuring in both traditional core regions and old semi-peripheries in western Europe and North America. By the turn of the century, the motor vehicle industry had become global in terms of ownership of carmakers, but actually, it was highly regionalised in terms of production and sales. Although all of the leading companies produced and sold vehicles in more than one region, only fewer than 10% of vehicles were produced in one world region, and shipped for sale in another (Brincks *et al.*, 2018), whilst cross-region trade in parts and components increased. Russo, Alboni, Carreto Sanginés *et al.* (2021) analyse the contribution of international trade in automotive components and parts in structuring the relative position and specialisations of countries over the period 1973-2017[1]. Their results support the hypothesis of the existence of a twin dynamic in clustering of international trade: increasing connections within the main clusters, and increasing connections across clusters. They also show that different relations emerge between core countries and their partners in the clusters. While in the USA-led cluster the structural changes determined a switch in the relative importance between the two main partners, Canada and Mexico, within the Germany-led cluster the strategy of German OEMs aimed to integrate the CEE countries (Czechia, Hungary, Poland, and Slovakia) in closer connections, while letting them maintain trade relations outside the Germany-led cluster, thus strengthening the cluster's connection with world trade. These results signal the creation of a hierarchical regionalisation of production and trade.

The intensification of monopolistic competition in a saturated market resulted in a proliferation of models, production in small batches, and declining profitability. The introduction of modular architecture allowed for the sharing of core components across vehicles and for the differentiation of vehicles sharing one chassis, thus reducing costs. In

[1] They use the multilayer module detection algorithm to address countries' relative positions in the bilateral trade network of automotive components and parts and to identify the creation of meso-entities in the overall trade network.

addition, companies attempted to create common production protocols for their factories and their suppliers. Modularity and body-on-frame allowed not only for greater variety, but also for greater flexibility in the location of production and in the choice of the country from which to serve the market: the production of a model could be concentrated in one country, and exported elsewhere, a process whose advantage is greatest where tariffs are zero or very low.

While countries in "integrated peripheries" saw incredibly fast growth in production, especially in components and parts, traditional core countries – Canada in North America, and many countries in Europe, except for Germany – lost ground in domestic car production. Competition through labour costs and Governments' incentives in the integrated periphery put pressure on labour in the higher-wage core countries. Due to cost competition, they suffered a process of delocalisation of many production phases, slipping down into "semi-periphery".

Saturated vs. expanding markets

The 2008-2009 crisis marked a watershed in the automotive industry, exposing the difficulties faced by the industry in a saturated market. It almost bankrupted many OEMs, triggering restructuring and closure of plants. The NAFTA region lost 32.4% of its production (from 12.9 to 8.7 million vehicles) and US carmakers had to be bailed out by the Government. While several plants closed, especially in the traditional automotive zone in the USA, others opened, the new industrial zones in Mexico being the most favoured (Klier and Rubinstein, 2017, Table 11). Thanks to lower labour costs, proximity to the US market, and tariff agreements, Mexico became a truly advantageous location: the only country, except for Canada, to ensure duty-free entry into the US market and with numerous trade agreements covering world markets. The two productive systems had become integrated to such a degree that we could refer to a regional auto parts-automobile chain with regional models, inputs, products and processes (Dussel Peters and Gallagher, 2013).

European producers were also badly hit by the crisis, although with different degrees of severity. An agreement for a gradual reduction of European production capacity along the lines of the US example, as advocated by Fiat's CEO, Sergio Marchionne, was impossible because of the involvement of many States, each determined to defend its industry and jobs, and above all because of the stern opposition of the German OEMs, which had been able to overcome the crisis thanks to the booming exports of their premium brands to China (and the USA). The pursuit of alliances, buyouts, and fusions characterised the consolidation of the industry to rationalise production and guarantee the presence and variety in the global markets. But it was the expansion of the Chinese market that drove OEMs' new location strategies.

Western OEMs began investing in China in the 1980s, but it is since its joining the World Trade Organisation (WTO) in 2001 that joint ventures' expansion has caught on (Smitka and Warrian, 2016). In a few years, China has jumped to the top of the list of world producers. With a huge domestic market that allures and locks in foreign producers, and a government policy determined to orient and subsidise the development of an innovative industry, Chinese policy differs from that of Mexico and the CEE countries, more similar to that followed by Japan and South Korea, which bought foreign technology, and developed their own brands. The Chinese Government has exercised tight control over its potentially huge market, limiting imports and FDI, banning exclusive foreign control by imposing joint ventures with local companies to promote their technological upgrade, and fostering competition between producers (foreign and domestic) to avoid being colonised, as befell

Mexico, Brazil, and Argentina. Despite the apparent success, until the pandemic outbreak the Government's target of developing a domestic industry, capable of consolidating around a few "national champions", was not entirely successful. What did emerge was a particularly unconsolidated industry, dominated by foreign brands, producing conventional high-end vehicles with almost no exports (Smitka and Warrian, 2016). According to Paba (2021), the joint venture policy hindered the creation of national champions: exploiting the clout that brands still command, especially in the premium class, foreign producers could retain control of most of the huge increase in the domestic production and sales of traditional, internal combustion engine (ICE) cars. Dependency is mutual, however: sales in China became an essential part of OEMs' overall production – in 2019, VW's output in China accounted for 38% of its global production, whereas GM's share was 45%, with similar values for Honda (Smitka and Warrian, 2016).

Things changed dramatically with the sudden advent of EVs.

3. A paradigm change

In the mature oligopoly that preceded the era of EV, carmakers opted for mergers and acquisitions to control competition and to consolidate market shares in a saturated industry. The race to EVs and AVs came as a shock. The new technologies require skills that have not, so far, been among the core competences of automotive engineering. Competition from new players, more adroit in the new technologies related to connectivity, autonomy, sharing, and electrification, threatened the established structure of the automotive industry. On the one hand, the huge investments required for the transition from internal combustion engines to EVs, the speed in innovating, and the urge to bring new ideas to market entail big risks. On the other, prospects of profit are attracting new investors from the most diverse sectors outside the automotive industry – such as tech companies, venture capital and private equity players, chemical industries, and battery producers. These players came to dominate investment in automotive, dwarfing the investment that the OEMs could afford[2]. Irrational exuberance – the combination of EV mania and the profusion of funds ensured by special purpose acquisition companies (SPACs) –[3] rewarded startups that had not yet produced profits, while neglecting legacy carmakers producing millions of vehicles. In 2021, Tesla stood out as the most aggressive and successful entrant, contending with the Chinese company BYD Auto the ranking as the world's largest producer of battery electric vehicles (BEVs). Its market capitalisation, greater than the sum of the market values of the main legacy carmakers, gives it a huge advantage in terms of investment capacity, which enhances its undeniable innovative ingenuity.

Only after an initial phase of inertia, did OEMs move quickly, announcing massive investments in the "new car". To comply with ever-stricter emissions regulation, take advantage of the new market opened by government EV subsidies, and, above all, catch up with new, challenging competitors in their own markets, carmakers have finally taken up the challenge, with almost all OEMs speeding up the production of EVs and hybrid vehicles, and committing to ambitious electrification goals until 2030.

[2] McKinsey (2019) reports that, of the more than 100 billion euros invested in mobility startups since 2010, 94% originated from players outside the automotive industry.

[3] The SPAC is a blank-cheque company that enables businesses to list without the usual scrutiny of a traditional initial public offering.

The speed of disruption, the need to make bets on multiple products, services, sectors, and technologies, the sheer size of the investments involved, and the uncertainty of the outcomes mean that strategic alliances to share R&D, resources, and projects have become a must. Thus, we have seen a shift in partnership archetypes away from familiar alliances within the value chain towards cross-sector strategic partnerships, joint ventures, and acquisitions of innovative technology startups. This trend has gathered momentum subsequent to Covid-19. Consolidation and partnership deals take place on an almost daily basis in EVs, autonomous driving, batteries, hydrogen fuel cells, sharing, and mobility (Alochet *et al.*, 2021; Russo, Alboni, Bonifati *et al.*, 2022). All these different sectors are simultaneously involved in this paradigm change and, as the automotive product changes, software and batteries are taking on an increasingly important role in the competitiveness and value of the vehicle.

Batteries are at the heart of the electric transition. Battery manufacturing is currently dominated by East Asian companies: in 2021, the top producing firms were from Asia, with China alone accounting for 77% of total production capacity (Ecorys, 2021). China had invested heavily and well in advance of traditional carmakers in EVs, possibly to leapfrog the internal combustion engine stage, where legacy western carmakers dominated. Its decision, a decade ago, to develop a full-fledged industrial value chain for EV batteries has endowed it with strategic power. Chinese battery makers have gained control over the key strategic resources of the lithium-ion battery industry, structured the industry, and defined and controlled its competition rules. The Chinese industry's current competitive dynamics are articulated around three core principles: industrial segmentation based on different battery chemistries, in-house development and production of strategic technologies, and the bargaining power of suppliers following customisation and diversification of transactions (Heim et al., 2021) – a strategy described by Wang and Wei (Wang and Wei, 2021) as "specialised vertical integration". Moreover, China invested on the whole spectrum of energy production and on the implementation of the electric charging infrastructure. Thus, parallel to its dominance in batteries, China rose to become the world's largest EV market and the first world producer, profiting from its first-mover advantage. In their effort to catch up, western OEMs entered into joint ventures with Chinese startups to reverse-engineer the new technologies back in their own production sites (Russo, Alboni, Carreto Sanginés *et al.*, 2021). Whether the changes the industry is going through will allow Chinese manufacturers to leapfrog the current stage and to control the new phase of electric and autonomous cars remains to be seen. China's explosive production of motor vehicles, its even higher domestic consumption, and its companies' rapid learning processes and past experience with other chains (such as the electronics and yarn-textile-garment chains) suggest that the country could start exporting automobiles on a large scale in the near future.

None of the global top-10 EV lithium-ion battery producers is European. However, based on current investment announcements, European production is expected to increase. Weight and cost of shipment are likely to govern the geographic location of new battery factories, as we shall argue in the next section.

With all major manufacturers rushing to launch BEV models, they have proved to be a significant bottleneck, made worse by the value chain disruptions following Covid-19. Moreover, the game is still open when it comes to clean/renewable energy technologies. The competition is being played out between batteries, fuel cells, and different, more ecological forms of fuels for traditional engines, as well as between different kinds of

batteries. Cost, time efficiency, and the availability of raw materials are crucial concerns in the choices made for batteries, and the lithium-ion battery industry for EVs faces the competition of solid batteries, which promise higher energy density and lower recharging times, and, above all, do not need cobalt. Technologies are still relatively new, and the costs of production high, as indeed is the uncertainty over future developments. OEMs and battery producers are jointly guiding the research into new, more efficient batteries.

Digitalisation and autonomous driving are the other frontiers of the automotive industry. The new digital technologies have lowered the previous high entry barriers that protected established ICE producers, allowing new entrants in the automotive sector. In fact, their international footprint is fundamentally different from that of other multinational enterprises: they can reach foreign markets with fewer assets and fewer employees overseas (Unctad, 2017). Large US (Alphabet, Amazon, Microsoft, Intel, and Nvidia) and Chinese (Tencent, Alibaba, Huawei, and Baidu) technology companies dominate the field. Although European (in particular German) OEMs are well placed in terms of innovation technologies, none of them can be considered top innovators (Ecorys, 2021). The increasing relevance of big data and IT devices is threatening to undermine carmakers' leadership, shifting the power from OEMs to Big Tech. However, this result is not inevitable. As argued by Ecorys (2021), one should not neglect the importance of well-established automotive brands in their ability to reach the consumer. Moreover, OEMs are striking back, making enormous efforts to pre-empt the market by entering joint ventures with digital companies and by increasingly investing in their own software solutions[4]. Finally, fully connected vehicle platforms, which allow for over-the-air software updates[5], may start new business models, enabling carmakers to generate recurring revenue streams from new services. Thus, "it is expected that consolidation will eventually follow with a few key players and their combined vehicle and service offers dominating the market. Who these players will be depends on the readiness of the current industry, including its factor conditions" (Ecorys, 2021, p. 51).

Old and new western players are also establishing or strengthening their ties with China to benefit from its huge market and skilful supply chains. As with electronics in the 1990s and 2000s, this strategy can backfire, with China outperforming its EV and AV competitors. Several Chinese companies are announcing ambitious expansion plans across the EV value chain in the USA and in Europe, alone or in partnership with local companies. With the car market regrouping, and old and new players repositioning themselves in the three macro-areas, the first movers' advantage is increasingly being challenged: Tesla's BEV share of the US market was expected to drop from 79% in 2020 to 56% by the end of 2021 (though it rose to no. 1 in European sales in 2021) (Lambert, 2021).

Countries' competition

Competition between technologies makes for an uncertain scenario, leaving room for a role for the State in fostering, regulating, and governing change. The EU and the USA

[4] German automakers are rapidly catching up. Mercedes-Benz is the first automotive company in the world to meet the demanding legal requirements for a level-3 system autonomous driving. See: Edward (2021).

[5] The over-the-air (OTA) updates are delivered remotely from a cloud-based server, through a cellular or Wi-Fi connection, to the connected vehicles. It is the same process as an update of smartphone or laptop. OTA updates enable a vehicle's performance and features to be continuously updated and improved. Technological advancements in these updates give automakers new freedom to constantly "freshen up" finished products remotely, with cars potentially getting better over time (Doll, 2021).

are trying to catch up with China in EV. Since its May 2018 Strategic Action Plan for Batteries, the EU has stepped up efforts and financial support to encourage risk taking and investment in research and innovation in the field, bringing together a set of measures to support national, regional, and industrial efforts to build a battery value chain in Europe, from raw materials to reuse and recycling, in derogation of the European state aid rules. Since 2018, many more "alliances" have followed: the European Clean Hydrogen Alliance in 2020, the 5G Automotive Association[6], and the European Raw Materials Alliance in October 2020, the European Alliance on Processor and Semiconductor Technologies in 2021 – the list is bound to go on growing.

The USA has joined in the game, combining regulation with incentives. While bestowing subsidies and incentives to attract new investments, Biden's 1.2 trillion dollars Infrastructure Investment and Jobs Act, signed into law on 15 November 2021, introduced the country's first national Local Content Requirements (LCRs) policy for renewables, essentially barring access to federal infrastructure financing unless the project uses US-produced materials (Hogan, 2021). The parallel Investment and Jobs Act, which passed the House in November 2021, and is expected to receive a formal Senate vote in January 2022, provides that, by 2030, 50% of the new vehicles sold in the USA must be EV or hybrid plug-in. It also offers 7,500 $ tax credits for EVs made in the USA, and 4,500 $ for cars made with union labour. The bill has drawn opposition from non-unionised companies, based on unjust discrimination. Unlike the workforces of the Detroit Three, in fact, most of the foreign-born automakers' and notably Tesla's employees are not unionised. Twelve foreign automakers with a non-unionised US workforce – including Toyota, VW Group of America, and BMW of North America – sent a letter to leaders in Congress opposing subsidies to EV purchases. Even so, all the major legacy carmakers have announced plans to build plants and massive battery factories in North America. The stakes are high, as the new entrants are likely to bring big changes in the unionisation of the workforce, potentially affecting wages and working conditions. The Tesla Gigafactory in Nevada provides a case in point: it pays lower wages than engine plants in Ohio, possibly setting a new standard for battery cell wages.

As battery fab plans mushroom, companies and Governments alike are forced to rethink how to build the battery value chain and where to source the parts and raw materials they need to make BEVs. It took 10 years for China to build its battery value chain. Its companies control much of the supply of the metals that go into batteries (nickel, cobalt, and manganese). In 2018, Chinese companies owned half of the largest cobalt mines in the Democratic Republic of Congo, the source of most of the world's metal supply – known as the "blood diamond of batteries" for the often inhumane conditions associated with its extraction. The carbon emissions from the production of batteries (including pollution from extracting the metals used in the batteries) are beginning to attract attention, as do investments in plants to recycle used EV batteries.

While massively subsidising the demand for EVs and the production of batteries, all the Governments have singled out clean hydrogen as an essential area to address in the context of the energy transition. After having invested for years in BEVs, in April 2019, the Chinese Government shifted the incentives from that technology to the production of

[6] Created in 2016 by three German automotive manufacturers (AUDI AG, BMW Group, and Daimler AG) and five major 5G patent holders (Ericsson, Huawei, Intel, Nokia, and Qualcomm), the association has now more than 130 companies.

hydrogen. The Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles now includes fuel cell technology and small unit production of hydrogen (Russo, 2019), a solution appropriate for countries that have dispersed locations of activities and residential areas. The European Commission estimates that Europe is highly competitive in clean hydrogen technology manufacturing, which offers a unique opportunity to bridge the gap accumulated in battery technology vis-à-vis the Asian countries (European Commission, 2020). According to representatives of Germany's mechanical engineering sector, the German industry already has the necessary expertise for electrolysis and hydrogen storage, but needs solid commitments from the Government to attract the necessary investment (Miller, 2020). France and Germany have already earmarked billions of euros for investment in fuel cell technology, and the Next Generation EU plan can help other member countries finance the green transition. Given the current state of technology, hydrogen has yet to become competitive for passenger cars. Still, fuel cells can be used for trucks, buses, and industrial use: as production goes up, the cost of electrolysis goes down, and more appropriate technical solutions for cars can become available, making it competitive with electric cars.

Increasingly, location is defined by Governments' policies. Everywhere, States and regions are vying – through subsidies, tariffs, or political pressure – to attract new investment, in an effort to reduce the impact of the ongoing transformations on the quantity and quality of employment. EU and US companies, in turn, put pressure on their Governments to solicit aid. The Federation of German Industries (BDI) issued a report urging the new Government to act quickly, triggering large-scale, low-carbon investments, and setting the right framework to ensure the country would transform its economy to reach climate neutrality by 2045 (Federation of German Industries (BDI) and Boston Consulting Group (BCG), 2021). And, of course, they urged for more funding to finance investment and to sustain demand in their markets[7].

All countries engage in different shades of protectionism. Although welcoming US and Asian producers, European Governments tend to favour their "national champions", on the assumption that they will be more responsive to domestic interests. This policy has potential implications not only for competition, but also for the geographic distribution of the industry. In fact, following the wave of consolidations, the number of European national champions seems to have reduced to two: German and French companies. The USA seems to rely more on its huge market, while resorting to LCRs to attract foreign companies. Finally, China is still keeping a tight control on FDI, allowed only in partnership with a local producer, except when helping the technological catch-up, as in the case of Tesla. Despite tight restrictions, US and EU carmakers have flooded the Chinese market, attracted by its size and the pre-eminence of its EV technology.

The paradigmatic change in the automotive industry, and the policy responses of the various Governments are bound to reshape the geography of vehicle production and to redefine trade agreements and regional alliances.

[7] The German industry, for instance, not only urged its Government to sidestep the debt brake by giving additional leeway to Kreditanstalt für Wiederaufbau (KfW), but it also called for a new, EU-wide bond programme to help poorer countries participate. They worry that it would be of little help for the climate if Germany alone switched to green production technologies, and it would be devastating for Germany's economy if it were surrounded by countries that could not afford to buy its EVs, and did not have the infrastructure to charge its hydrogen trucks (Federation of German Industries (BDI) and Boston Consulting Group (BCG), 2021).

4. Winners and losers: labour and peripheries

The impact on labour

The automotive industry has been one of the most important growth engines for the developed countries of Europe and North America, and it will continue to play an important role, albeit in forms that are currently highly uncertain. Its cross-sector connections are still relevant for many countries, but its path of development, and the employment issue are key. Digitalisation and electrification define a completely new product, requiring new components and new skills: less engineering and more software, and different refuel and mobility infrastructures. Moreover, the EV requires far fewer components, as alternative powertrains are less labour-intensive than conventional internal combustion engines. While the engine of a VW Golf contains 113 moving parts, the equivalent section of an electric Chevrolet Bolt has three: producers of parts for traditional engines risk being cast out (Campbell, 2020). According to some estimates, the industry could shed 30% of jobs, with more jobs lost, and new skills demanded downstream, in services and repairs. Recent studies suggest that, when battery production is considered, employment in the automotive sector is likely to be hit less hard than initially expected, since BEV value chains are probably not significantly less labour-intensive than ICE ones (Boston Consulting Group, quoted in Ecorys, 2021, p. 32). They are, however, shifting the demand for labour and skills away from metal and machinery workers towards researchers, engineers, and technicians with electrical, electrochemical, mechatronics, software, and industrial skills.

Traditional Tier-1 suppliers and their value chains are at the forefront of technology changes. While they struggle to incorporate the new skills, a large segment of the supply chain connected with the internal combustion engine is expected to disappear. Producers of parts and components may also be called to bear the brunt of the monetary costs of the transition. In the past, when the fall in demand in traditional markets, and the need to invest massively in new markets, products, and technologies put OEMs under severe pressure to gain flexibility and to cut costs, the burden of making savings fell on suppliers and labour. Parts producers bore the brunt of the adjustment. Even in this phase, they are the most exposed to "discount" requests. Unlike Volvo's CEO, Hakan Samuelsson, who argued in favour of a policy that took complexity into consideration in order to obtain quality and low cost[8], Stellantis's CEO, Carlos Tavares, announced his strategy of aggressively pursuing ways to save money with suppliers, maintaining that they have to absorb the extra cost that comes with the transition to EVs.

Peripheries

While job losses will not spare core countries (Simonazzi, Carreto Sanginés and Russo, 2020), for the peripheries, mostly specialised in ICE vehicles and parts, two main challenges loom in the near future. On the one hand, faced with disruption of the fully integrated, global supply chain, core countries could implement policies to defend their own industries and employment, with companies reshoring or even re-internalising production stages, thus threatening the survival of a huge number of producers in the peripheries. On the other, the radical transformation of the industry is changing core competences, requiring skills that have not hitherto been among the core competences of automotive engineering. The consequences could be different for the two peripheries.

[8] "Carmakers need to take control of functionality in the car, rather than just buy something out of a box from a supplier […] batteries, the computing platform and software […] need to be vertically integrated" (Bolduc, 2022).

In semi-peripheries, already plagued by a loss of final production, the survival of the industry relies on its ability to reinvent itself, embarking on frontier technologies that have less to do with the traditional automotive industry but, for this very reason, are less developed in these countries. This is especially true of software and digital technologies, which are dominated by actors outside the industry, or are concentrated in the OEM's headquarters. As the strategic functions are externally controlled through foreign ownership, there is no guarantee that the production of new components for EVs and AVs will be located in the same places where ICEs and their components are produced now (Krzywdzinski, 2019). The long-term sustainability of their industry faces serious challenges.

Integrated peripheries face similar challenges, but have two possible advantages over semi-peripheries. First, their automotive industry is based on production in state-of-the-art factories and technologies, as they attracted foreign investment aimed at creating an integrated and efficient production network for the export of parts and components, and, recently, cars. As the transformation of the industry will take time, with ICE vehicles diminishing and EVs not yet at scale, ICE production will likely migrate to these plants in lower-cost regions. Second, the cost advantage of locating battery factories close to assembly plants, as well as lower labour costs and fiscal benefits, can favour integrated peripheries. As shown by data of Fitch Solution (2021), most of the battery plants in operation, under construction, planned, or announced are concentrated in the north-eastern part of Europe, especially Germany and the CEE countries. Their absence in the south should be noted, apart from two plants in Italy (one under construction and one announced). However, this is a long way from 2019, when there was a limited number of gigafactories, driven by Tesla's plant in Nevada (USA). Now, a map would be out of date within a week. The Spanish research group CIC EnergiGUNE has developed an interactive map of battery gigafactories being developed across the world, which shows the mushrooming of factories in Europe (Flaherty, 2021). Conversely, as labour demand moves away from metal and machinery workers, integrated peripheries are likely to face more severe shortages of skilled labour with the right competences, as their productive structure is highly specialised in the automotive sector, with little evidence of positive spill-over effects on the rest of the economy. While skills shortages are widespread across the industry, semi-peripheries could benefit from a more diversified structure of production and job skills.

Finally, geopolitical and core countries' domestic policy considerations will affect the location strategies of the main actors, and the future division of labour. Concerns about the resilience of the value chain and core countries' defence of employment could lead to policies that favour re-shoring. In the case of the USA, for instance, Barrett and Bivens (2021) warn that the decline in employment and job quality can be averted only if the shift to BEVs is accompanied by strategic investments in manufacturing and job quality in the US automotive sector. Improving domestic capacity in powertrain components for BEVs, and boosting the market share of domestically produced vehicles are likely to become a generalised policy approach. Subsidising the acquisition of domestically produced BEVs with tax credits, favouring re-shoring of parts and components, and subsidising investment in battery fabs, Governments are attempting to affect the competitiveness of their locations and to avoid job losses in the transition towards electrified mobility. Peripheries and semi-peripheries must catch up in the overall transformation of the automotive industry, navigating the economic strategies of foreign companies, geopolitical concerns of Governments, trade wars, and (the undoing of) trade treaties.

The case of Mexico

Mexico represents a significant case study for the analysis of the impact of trade agreements and digital transformation on the location policies of big multinationals in an integrated periphery, and their effects on the domestic value chain. The development of its automotive industry has been heavily dependent on FDI. The dependency of the Mexican automotive industry on the strategic decisions of global players is considered a factor of great vulnerability, especially in a context of rapid change in the patterns of consumption, technologies, and geopolitical turmoil. According to some scholars (Castellanos *et al.*, 2010; Carrillo, 2018), the foreign-owned, technologically advanced part of the industry has been insulated from the rest of the domestic value chain. It was argued (Carreto Sanginés, Russo and Simonazzi, 2021) that digital and Industry 4.0 technologies could play a key role in starting a sweeping transformation along the entire supply chain, providing better quality control and smoother flow of information within supply chains with just-in-time production, enhancing product quality control together with process and product innovation. They could also provide the flexibility required to optimise the production process without relying solely on labour flexibility, which has so far been the main resource for adjustment. To meet these challenges – it was maintained – changes were needed in several interrelated domains that go beyond digital traceability of products and processes: labour up-skilling, energy and digital infrastructure, logistics, and integrated modernisation of transport.

The rapid change in the global context has changed this scenario. Much of the future development of the industry is in the hands of the USA, its senior partner in the USMCA agreement. At first, the conclusion of the new treaty between the USA, Mexico, and Canada brought relief to Mexican companies and policymakers. The labour clauses of the treaty did not seem to worry producers in Mexico too much, since the new, stricter conditions on rules of origin were expected to attract new firms willing to divert production from other developed or emerging economies to gain access to the US market and, at the same time, to take advantage of cheap Mexican labour. Optimism has considerably declined since then. As the radical transformation of the industry threatens the survival of a huge number of producers in the peripheries as well as the core, core countries are implementing policies to defend their own industries and employment from the anticipated disruptions.

Building on its huge potential market, the USA is attempting to repeat the policy of the 1980s, when the Detroit Three learned from foreign firms, and the US automotive industry regained competitiveness mainly due to the accelerated migration of Japanese and European manufacturers to the USA. Biden's bill, described in the previous section, has drawn opposition from foreign diplomats, who raised concerns that the bonus violated international trade agreements. On 29 October 2021, the ambassadors of 25 countries wrote a letter to Congress stating that the provision "tarnishes the spirit of trade laws that seek to establish the free and fair movement of goods"[9]. Canada and Mexico also opposed the climate policy, arguing that it was "inconsistent" with the USMCA. Both countries considered the possibility of imposing tariffs on US products.

US protective policies, coupled with strained US-China relations, frustrate the Mexican Government's expectations of the opportunities offered by the USMCA. Indeed, the treaty

[9] Ambassadors of Austria, Belgium, Canada, Croatia, Cyprus, Czechia, Estonia, EU, Finland, France, Germany, Greece, Ireland, Italy, Malta, the Netherlands, Poland, Romania, Slovakia, Slovenia, South Korea, Spain, and Sweden.

was supposed to attract foreign companies eager to produce for the US market while taking advantage of duty-free exports and low labour costs. Following the US Government's new policy, Chinese and European companies are more likely to enter the US market directly, attracted by government subsidies and restrictions, and the country's technological leadership in digital and software architecture, bypassing Mexico.

5. The world to come

The automotive industry is going through a paradigm change. Competition from new players and the new technologies related to connectivity, autonomy, sharing, and electrification (CASE) threaten the established structure of the automotive industry. These changes affect the entire supply chain, and have the potential to redraw the boundaries of the sector, redefine key players and sourcing practices, and affect the relative advantage of countries and regions, reshaping existing industrial geographies.

Faced with ever-stricter EU emissions regulation and pressed by new competitors, carmakers have finally accelerated the production of EVs and hybrid vehicles. The automotive industry's old core, which based its supremacy on engineering excellence, is now committing large sums to the new technologies, forging alliances upstream and downstream in the new value chains, and exploiting the advantages accruing from its command over production technologies. There is a huge market to exploit, and market dynamics and competition patterns are in constant flux.

Governments are trying to shield domestic production and employment from the effects of the transition by subsidising investments in new plants and technologies. More or less covered protectionist policies influence old and new players' investment and market penetration policies. With huge subsidies for new fabs and domestically produced cars in the USA, the location can become attractive again. The US and Asian producers are investing in the EU to gain a chunk of a rapidly expanding market while benefitting from generous investment subsidies. And US and EU carmakers keep their hold in the Chinese market.

With the car market regrouping, with old and new players repositioning themselves in the three macro-areas, attracting new Tier-1s and new value chains, competition will move downstream, to autonomous driving and mobility, and upstream, in green technologies for batteries and hydrogen, semiconductors, and control of strategic raw materials. Competition between technologies makes for an uncertain scenario, leaving room for the role of the State in coordinating, supporting, and governing the change. Trying to bridge the gap with South Asian competitors, European and US OEMs have already committed large sums to the battery technology. Conversely, the competences of incumbents are no longer sufficient to master digital and mobility innovation. Since R&D in the new software and digital technologies are mostly developed in regions other than those dominated by OEMs, even the automotive industry's old core that based its supremacy on engineering excellence risks losing ground. Although the OEMs are striking back, if the car follows the destiny of the computer, where the value is increasingly in software, the distribution of profits between the various players will be affected[10].

[10] According to some reports, profits will shift even more towards new technologies and services, with more than 80% of the industry profit pool originating from CASE technologies and new business models.

The current automotive transition is likely to open the way to a new restructuring of the comparative advantage of nations, with important consequences on the quantity and quality of employment and on the fortunes of countries and regions. Eventually, not only the car, but the whole car industry will be completely transformed.

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