The automotive industry towards environmental sustainability.

Some evaluations on China, Europe, and Italy.

by

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Paper presented at the workshop
"The Italian Automotive Supply Chain between Ecological Transition and Competiveness" organized by Federmeccanica and Anfia.
CUOA Business School - Altavilla Vicentina CUOA, Vicenza July 11, 2024

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1. Producing an electric car is different from producing a traditional car.

<u>The electric motor has broken down barriers</u>

In its history car has often been considered a "mature" product. For example: i) in the early '70s, only to discover that the oil crisis would pose extraordinary efficiency challenges; ii) at the end of the '80s, only to discover that electronics would revolutionize engine management; iii) in the '90s, only to discover that pollution issues (Euro 1 - Euro 6) set further difficult challenges. In short, many times it seemed that the target was stationary and already reached, but each time we then realized that it was not so. The pressure arising from new challenges has contributed to consolidating the excellence of Western automotive over time.

Today we face another major transition with not yet fully defined contours concerning new forms of traction where electric traction will be predominant. All this will lead to enormous changes in the structure of technological leadership and, consequently, market leadership.

As is well known, the design and construction of vehicles with internal combustion engines (ICEs) represent a challenge of enormous complexity. For many years this type of engine has been a technological excellence firmly in the hands of Western countries, with Europe in the lead.

The progressive restrictions on pollutant emissions (Euro 1, …, Euro 6) have made necessary to develop increasingly sophisticated mechanics and that has implied increasingly sophisticated electronic controls and with increasingly tighter tolerances. The car has ceased to be purely mechanical and has become a "mechatronic" product; the measurement of tolerances has moved over time from tenths of millimeters to microns. As higher and higher performances were required, the tolerances, the play on components, became more and more microscopic: this determined the need for deep knowledge of mechanical processing and assembly processes.

For example, consider the tolerances necessary for the operation of a fuel injector: to ensure the right flow, the so-called gap within it must be, in some cases, below the micron; obviously, this level of accuracy must be guaranteed for all produced parts. In these cases, statistical process control gives way to 100% production control, i.e., processes that measure the single produced component in real time. This implies that producing millions of high-precision pumps and injectors poses new challenges and requires very sophisticated technologies and skills.

In recent decades, this has allowed Western manufacturers, particularly Europeans, to hold firmly in their hands technological leadership and, therefore, market leadership. Over a long time deep knowledge of physics and chemistry has been incorporated into engineering processes, and this complex knowledge has become pervasive in the culture of Western automotive companies and supply chains. A significant part of Italian manufacturing, driven by increasingly stringent technical specifications imposed by major manufacturers, has thus reached absolute levels of excellence.

Additionally, in the great tradition of Italian, German, and Japanese sports car manufacturing, sophisticated process control is combined in a refined way with purely aesthetic aspects thanks to the work of extraordinary designers, engineers, craftsmen and skilled workers.

It is evident that Chinese manufacturers have made extraordinary progress in internal combustion technologies and in style. However, achieving leadership in internal combustion engines would be very costly and probably not even in line with their medium-term development strategies.

On the other hand, an electric motor, although it must guarantee increasingly higher performances, has a much simpler design and realization as it derives from widely experimented technologies and fields. In fact, the electric motor for vehicles has a history that intertwines with various uses and applications over time. Before their prevalence in cars, electric motors were used in industrial applications, railway transport, naval applications, etc. In particular, trains, tram were among the first mass transport vehicles to adopt electric motors.

These applications and the continuous development of electric motor technology have significantly contributed to their adoption in cars and opened the way to much more competition. The relative "simplicity" of electric motors' construction explains why there are many companies, even small ones, capable of designing and manufacturing electric powertrains and why significant companies that have established themselves in other sectors find it relatively easy to enter the electric automotive sector: in particular, BYD which came from the cell phone battery sector (see later), and more recently, the smartphone manufacturer Xiaomi.

A synthetic comparison between internal combustion engines and electric motors highlights the following main aspects:

1. Fewer moving parts compared to ICEs. A typical electric motor has few key components: mainly the rotor, the stator, and the bearings. This contrasts sharply with the complexity of an ICE, which includes pistons, pumps, injectors, crankshafts, valves, camshafts, and various other mechanical components. This results in less mechanical complexity for electric motors.
2. Modular design. This facilitates their production and maintenance. This modularity also allows for easy scalability in terms of power and torque to meet different applications by simply varying the number of motor modules used. Conversely, an

internal combustion engine's performance depends on the design and optimization capability of each component in the system: the relationships between the pump, injectors, control units, etc., are complex and manageable only after many years of study and experience. Emissions management also involves handling complex micro-equilibria where each element - although microscopic - is crucial for the overall performance, especially in terms of emissions.

3. The production and assembly of electric motors are simpler and thus more easily automatable than ICEs, thanks to their lower complexity and fewer parts. This can lead to lower production costs and shorter assembly times. This is also associated with a significant reduction in required labor: for example, producing a diesel engine requires - with equal power - about ten times more personnel than producing an electric motor.
4. Reduced maintenance: the simpler construction of electric motors translates into lower maintenance needs compared to ICEs. With fewer parts subject to wear and no need for oil changes, filters, belts, or exhaust system maintenance, electric motors can offer greater reliability and reduced downtime.

   The issue of the durability of electric vehicle batteries certainly requires a separate discussion.

<u>Electric car and autonomous driving</u>

Electric cars do not inherently have more potential for autonomous driving compared to internal combustion cars, but there are some reasons why electric car manufacturers might be more advanced in autonomous driving technology. These cars are built on newly conceived platforms and can thus be designed from the start to integrate advanced technologies, including autonomous driving systems (sensors, wiring, control units, etc.). In other words, the needs posed by the design of the electric component and those posed by autonomous driving can be managed jointly and simultaneously. It is simpler to do this "starting from a blank sheet" rather than adapting to new needs an ICE vehicle with an overall architecture that has consolidated over the years.

Moreover, electric car manufacturers, such as Tesla and major Chinese manufacturers, have a different cultural background and mentality than traditional ones: they often have a strong orientation towards digital technologies and invest significantly in research and development, including autonomous driving. It is not surprising, therefore, the interest of Apple and Google in this topic.

It’s no surprise therefore that China has declared its intention to achieve leadership in both battery electric cars and autonomous driving development, thanks also to massive investments and studies in artificial intelligence.

In essence, the development of electric cars has broken the barrier associated to the extreme technological complexity of ICEs, effectively paving the way for new market leadership.

Both electric and internal combustion vehicles will increasingly need electronics and software, benefiting new companies entering the market with software development experience. For example, de Meo (2024) predicts that the software's impact on the cost of a car is destined to double between now and 2030, going from 20% to 40%: the mobility software market should triple by 2030, exceeding $100 billion.

Today, therefore, market leadership passes into the hands of those who have raw materials for batteries and electronic circuits. The conquest of leadership will depend less and less on the ability to manage microns and more and more on the ability to manage bytes, silicon, and battery chemistry.

2. The Recent Successes of Chinese Cars

2.1. The Chronicle of an Overtaking

In the last three decades, the performance of the Chinese automotive sector has been extraordinary. Consider that in 1998 the number of cars produced in China represented (OICA data) less than 40% of the number of cars produced in Italy and, respectively, 4%, 6%, and 10% of the cars produced in the EU15, Japan, and the USA.

The speed of this overtaking is impressive: just five years later, in 2003, Chinese car production surpassed that of Italy, in 2006 that of the USA, in 2007 that of Germany, in 2008 that of Japan, and in 2010 that of the entire EU15. Since 2009, China has been the largest car-producing country in the world.

In 2022, the number of cars produced in China was over 50 times the Italian figure, almost 7 times the German production, 2.8 times the EU15 production, and over 13 times the USA production. In 2023, over 30 million cars were produced in China (CAAM).

Certainly, this extraordinary dynamics is partly attributable to the simultaneous growth of China's overall weight in the global economy: between 1998 and 2022, the Chinese GDP at purchasing power parity (IMF source) went from being less than twice to almost ten times that of Italy; similarly, the Chinese GDP in the period went from being less than a third of the US GDP to being 20% higher. Within the context of the exceptional dynamics of the overall Chinese economy, there still is something extraordinary in the overtaking dynamics in the car production sector as well.

Also noteworthy is that if, instead of considering the mere number of cars produced, we were to consider the value of production, the dynamics of the overtaking would probably be further accentuated since the price and quality difference between Chinese and Western cars has certainly reduced.

If we focus on 2023 (CAAM data), the first year after the end of "zero Covid" policies, an impressive and varied production capacity emerges: out of a total production of over 26 million cars, vehicles with internal combustion engines (ICEs) represented the vast majority (about 17 million, over 65.2%), battery electric vehicles (BEVs) were in second position (6.2 million or 23.9%), and plug-in hybrid vehicles (PHEVs) were the least numerous component (about 3 million, approximately 10.9% of the total). Between 2022 and 2023, the relative weight of ICE vehicles decreased from 71.9% to 65.2%, the relative weight of BEV vehicles increased (from 21.5% to 23.9%). However, the relative weight of PHEV vehicles increased at a higher rate than BEV vehicles: from 6.6% to 10.9% of the total. In 2024, the trend towards the affirmation of PHEV vehicles continues: in the first quarter, sales of hybrid and battery electric vehicles increased compared to the previous year by 81.2% and 13.3%, respectively.

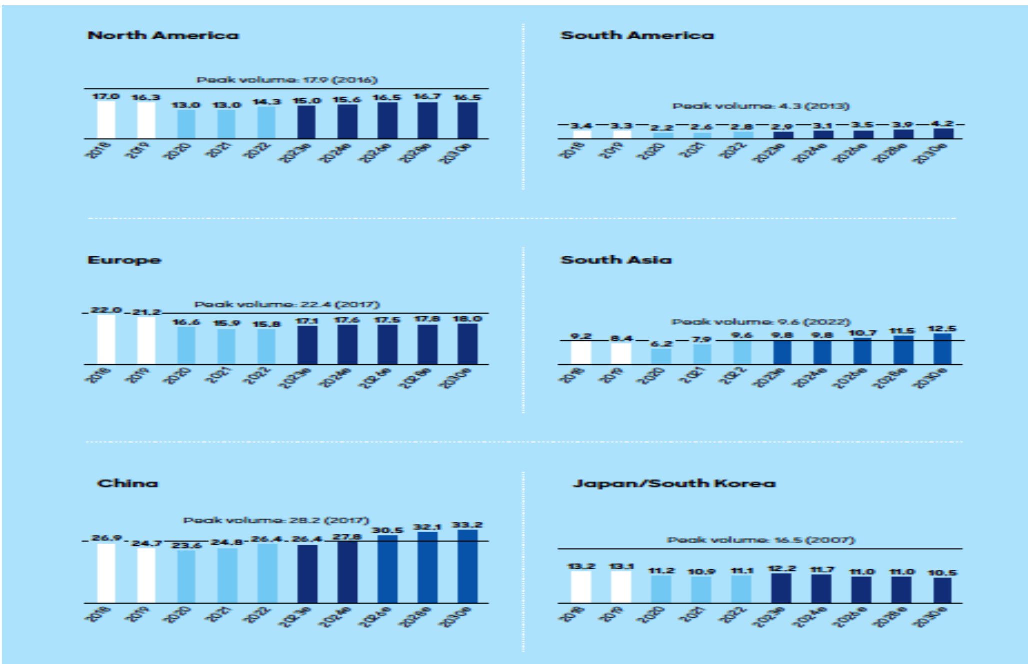
The Export

China is now the largest car exporting country in the world: Chinese exports, which in 2018 were 1/4 of Japan's, reached 5.3 million vehicles in 2023 against Japan's 4.3 million. The automotive sector's trade balance went from a $31 billion deficit in 2020 to a $7 billion surplus in 2022. Consequently, for the first time in history, the European automotive trade balance recorded a deficit in December 2022. This latter fact dramatically called European institutions' attention to the absolute and relative decline of the automotive industry in Europe.

It should be noted (CAAM source) that in December 2023, about 2.7 million cars were produced in China: projecting this monthly figure on an annual basis results in a hypothetical production of over 32.5 million cars, about 24.8% more than the total Chinese production in 2023 (26 million): there is already today a considerable potential capacity to expand production levels. If the internal market is not able to absorb this enormous production capacity, the pressure to export Chinese vehicles will become increasingly strong. It should be noted that there are no easy shortcuts for Europe: closing to the import of Chinese cars would hurt European consumers and expose European producers to the risk of retaliation by Chinese authorities. In particular, the market share of Chinese producers in Europe has dropped from 28% to 21% between 2019 and 2023 (see Figure 1). Despite this unfavorable trend, the VW group (Volkswagen + Audi) was the top seller in China in 2023 (Figure 2) with a total market share of 13.3% against BYD's 11.8%. BMW is the only other European manufacturer in the Top 10 with a market share of 3.2%. In 2023, VW achieved about a third of its global turnover in China, selling about 3 million vehicles. It is evident that Europe has much to lose from a hypothetical trade war in the automotive sector with China: China is currently able to replace a large part of the cars produced in China by European brands.

If we instead refer to only electric vehicles (Figure 3), a very different picture emerges with Volkswagen dropping to 6th place (4.21%) in January 2024 sales and being the only European brand among the top 10 (Figure 4). European manufacturers face significant difficulty maintaining positions in the new electric mobility sector.

Fig. 1 Production of cars in the world



Source IHS, Roland Berger/Lazard

Fig. 2: Top-Selling Brands in China

Top-Selling Brands in China in 2023

CarNewsChina.com

Rank	Brand	Sale	YoY Change	Share
1	BYD	2,571,109	+43.3%	11.85%
2	Volkswagen	2,228,635	-0.2%	10.27%
3	Toyota	1,702,773	-3.8%	7.84%
4	Honda	1,193,019	-12.3%	5.50%
5	Changan	962,061	-3.5%	4.43%
6	Geely	914,752	+9.6%	4.21%
7	Wuling	843,103	+7.8%	3.88%
8	BMW	705,163	+7.8%	3.25%
9	Nissan	687,110	-14.3%	3.17%
10	Audi	664,607	+11.3%	3.06%
Whole Market		21,706,000	+5.6%	100%

Fig. 3 Top selling brands in China

Top-Selling Brands in China in 2024.01

CarNewsChina.com

Rank	Brand	Sale	YoY Change	Share
1	Volkswagen	209,476	+41.5%	10.29%
2	BYD	191,122	+43.4%	9.39%
3	Toyota	141,689	+35.1%	6.96%
4	Changan	130,408	+52.7%	6.41%
5	Honda	129,638	+102.6%	6.37%
6	Geely	120,019	+72.6%	5.90%
7	Wuling	73,064	+43.4%	3.59%
8	BMW	68,873	+21.3%	3.38%
9	Chery	62,178	+192.5%	3.06%
10	Nissan	58,575	+43.0%	2.88%
Whole Market		2,035,000	+57.4%	100%

Fig. 4: Top-Selling Pure EV Brands in China

Top-Selling Pure EV Brands in China in 2024.01

CarNewsChina.com

Rank	Brand	Sale	Share
1	BYD	98,423	26.18%
2	Tesla	39,881	10.61%
3	Wuling	27,557	7.33%
4	Aion	21,115	5.62%
5	Changan	19,472	5.18%
6	Volkswagen	15,828	4.21%
7	Zeekr	12,537	3.33%
8	Geely	11,876	3.16%
9	Nio	10,055	2.67%
10	Leap	8,849	2.35%
Whole Market		376,000	100%

<u>From Catch-up in ICEs to Overtaking in BEVs</u>

China's success in the field of electric cars is, if possible, even more striking: in 2023, over 6 million battery electric vehicles (BEVs) were sold (+22% compared to 2022); during the year, China produced over 9 million electric vehicles (BEV + PHEV) against 3.3 and 1.6 million produced, respectively, in Europe and North America (source CAAM and BloombergNEF, 2023).

The Chinese strategy to recover the significant technological gap in the internal combustion engine (ICE) sector has had various articulations: privatization of the sector, significant investments in R&D and strategic alliances with leading Western companies. As is well known, Western companies can only produce cars in China within a framework of cooperation with local companies. This has allowed for the rapid dissemination of skills and technological knowledge, which - also through local supply chains - has improved the quality of local productions.

This strategy has met with the favor of major European automotive companies since this option - though limiting - still allowed them to participate in the huge growth of the local market. Chinese producers, despite having largely (or totally) caught up with Western ICE producers, probably faced the impossibility of making a real "technological overtaking" over them. There are indeed many skills and excellences of European and American producers, and it would have been perhaps impossible to find a genuinely Chinese strength point to allow them to make such an overtaking.

In contrast, in the emerging sector of battery electric cars (BEV), there were conditions for an overtaking that has indeed been realized. These conditions are manifold: i) the lower technological complexity of electric vehicles; ii) the absence of absolute Western excellence in the field of batteries; iii) China's ability to access low-cost rare earth supplies that Europeans do not have; iv) the greater relevance of electronics in electric vehicles; v) the ability to leverage, also thanks to intelligent economic policies, the enormous size of the domestic market and the presence of exceptionally extensive and concentrated urban agglomerations.

The lack of recognition of Western supremacy in the field of electric cars might explain the government's decision in 2017 not to extend to Tesla the obligation to have a local partner to produce cars on Chinese territory. Tesla, indeed, inaugurated its plant in China in 2019 without local partners.

2.2. The Emblematic Protagonist of the Overtaking: BYD

The Chinese company BYD paradigmatically interprets the metaphor of the "overtaking" of Chinese electric cars over Western ones.

Founded in 1995 by Wang Chuanfu, a 29-year-old chemistry graduate, BYD began its activity producing cell phone batteries; in seven years, it achieved 65% of the global production. From this excellence in the field of small cell phone batteries, production quickly expanded to include batteries for electric cars.

In 2003, BYD entered the automotive sector by acquiring Xi’an Qinchuan Automobile, an old struggling public company, giving birth to BYD Auto; by coincidence, 2003 was also the year Tesla was founded.

In 2005, the first BYD-branded car hit the market, and in 2008 the first plug-in car; a year later, the first battery electric car (BEV) and an electric bus (range > 300 km per charge) were released.

In 2007, the internal effort in producing electronic components justified the spin-off of BYD Electronics.

In 2010, BYD formed a joint venture with Daimler, and in 2014 a BYD PHEV was the best-selling hybrid vehicle in China.

After investing heavily in the technological component, in 2016, the recruitment of W. Egger (formerly of Alfa Romeo, Audi, Seat) as head of design signaled BYD's awareness of the need to care for aesthetic aspects to break into not only the Chinese market but also Western markets.

The European debut happened five years later, in 2021, with the first sales in Norway, certainly the most promising European market for electric cars, thanks to significant public incentives for consumers and the absence of local producers.

In 2022, BYD ceased the production of entirely internal combustion vehicles, marking a specialization towards electric mobility.

In the first quarter of 2023, BYD surpassed VW as the best-selling brand in China; in the last quarter of 2023, BYD sold 1.6 million electric vehicles, surpassing Tesla and leaving European producers far behind (the first among them, the VW group, sold less than 400,000 electric cars).

Between 2020 and 2023, global sales increased sevenfold (from 427,302 to 3,024,417 vehicles).

In December 2023, the construction of a production plant in Hungary (Szeged) was announced, confirming the intention to reach the European market not only with vehicles produced in China and imported by sea (in January 2024, BYD's first roll-on/roll-off ship for exporting vehicles to Europe entered service) but also with vehicles produced within the European Community.

The rapidity of decisions, the ability to form strategic alliances, and the courage to take new paths characterize BYD's history; the "R&D first" philosophy has been central to all actions over these decades. However, BYD's most peculiar feature is the verticalization of processes. For example, Wu and Wang (2024) show that 75% of the components of a BYD Seal are produced by group companies compared to 68% of the components of a Tesla Model 3 produced in the USA, 46% of a Tesla Model 3 produced in China, and 35% of the components of a VW ID.3 produced in Germany. For these four models, the share of components bought externally on the international market is 8%, 32%, 3%, and 62%, respectively. The remaining component share is purchased from Chinese companies outside the group (17%, 0%, 51%, and 3%, respectively).

BYD today has four major areas of activity: automotive, trains, electronics, and batteries.

The recent investigation conducted by the European Commission preliminarily concluded that BYD has benefited from state aid, but it is undeniable that if such aids have indeed existed, they have been used very effectively. It would be pretentious to attribute BYD's successes exclusively to such aids. BYD's success certainly does not depend only on the lower cost of labor in China but on the intelligent use of workers' creative capacities;

it’s not just a story of low-cost, hard-working and low skill workers but also a story of R&D and full use of brain power.

BYD's choice to focus on BEV and PHEV vehicles is certainly courageous but exposes the company to risks in the face of potential slowdowns in the electrification process.

Even in China, the significant spread of electric cars is still concentrated in a few major cities: in 9 major urban areas where 9.7% of the total Chinese population lives, 64% of electric vehicle sales are concentrated. It is certainly possible to imagine the development of electric cars in different contexts, but this has not been demonstrated to date.

In Europe, the transition to electric - at least as designed by current European regulations - poses unresolved questions of economic, industrial, and social sustainability: the price of electric vehicles remains high, and the European automotive industrial fabric faces significant difficulties in converting in such a short time. Additionally, the process of building charging infrastructure is currently lagging, as are the enhancement of the electric grid and its rebalancing in favor of renewable sources.

In the USA, similar issues to those in Europe arise, with the addition of even ideological problems: a recent study (Davis et al. 2023) highlights a strong and lasting correlation between the prevalent political orientation in various US counties and the adoption of electric vehicles. Between 2012 and 2022, about half of all electric vehicles were sold in the 10% of counties with the highest incidence of Democratic votes, and about a third went to the 5% of counties with the highest incidence of Democratic votes.

The 100% tariff on the import of Chinese electric cars closes the American market to BYD, which will likely have to consider opening a plant in the USA or Mexico to access the market.

BYD is the Chinese producer that suffered the lowest tariffs among those temporarily imposed by the European Commission in June 2024; a recent study by the Italian Trade Agency (2024) notes that BYD operates in Europe with very high margins: for example, the "Atto 3" model costs about €38,000 in Italy while it is sold for about €15,400 in China. The Financial Times states that BYD currently has margins above 20%, and assuming the tariff is only 50% passed on to consumers, BYD would retain a net margin of 8.6%. Even after sanctions, BYD would continue to be much more competitive than European competitors.

In light of the considerations made here, it is not surprising that many major Western automotive groups (e.g., Daimler Benz, Ford, and GM) have recently announced a downsizing and slowing down of their transition to electric, maintaining a diversified product offering for a longer time.

2.3. Public Policies to Support the Demand for Chinese Electric Cars

Timely and Consistent Policies

China introduced the first incentives for purchasing electric cars in 2009, right after the USA and before the main European countries; four years before Italy, six years before Germany. Even in the case of the transition to electric cars, the Chinese government adopts an experimental and gradual approach. The expression "cross the river by feeling the stones" (摸着石头过河) refers to the idea that to successfully make a transition, it is appropriate to try different paths, verifying the solidity (and slipperiness!) of the stones on which one steps. Translated into the case of electric cars, this approach translates into a sequence of interventions over time with a progressive "sharpening of policies," a gradual territorial expansion of the policies' target audience, and an enlargement of the economic policy tools being used. The number of cities involved went from 12 in 2009, 25 in 2011, 39 in 2013, to incentives on a national basis in 2015 (Li et al. 2018 and Liu et al. 2023).

Public Procurement

Purchases by public entities have the dual effect of directly supporting the demand for a good and demonstrating to the general public its qualities. In this specific case, the purchase of electric public transport vehicles supports the demand for such vehicles in the early stages of the development of these productions and "demonstrates" to citizens that these vehicles are functional and safe. The program initially (2009) focused on purchasing vehicles and buses by the public sector and only later (June 2010) the incentives were extended to private sector purchases. Already in 2017 (De Podestà et al. 2023), 100% of Shenzhen's public bus fleet was electric (PHEV and BEV for a total of over 16,000 vehicles). It is estimated (Liu et al. 2023) that by the end of 2020, Chinese public entities had purchased a total of 550,000 electric vehicles (cars, buses, and special vehicles for waste collection...). The role of public administration as a purchaser and demonstrator of technology has been very important in China, while in Europe, this role has been marginal; for example, in Italy, out of about 37,300 cars owned by public administrations, only less than 1,200 (about 3%) are electric, and 70% of the total is Euro 4 or lower.

Financial Incentives

Financial incentives are active both at the state and regional levels, but in 2015, the role of regional governments was limited by establishing that they cannot offer subsidies higher than 50% of state ones.

The financial subsidies (see below) are progressively parameterized against increasingly high "technological bars" and consider an increasingly wide and detailed set of technological parameters. Only vehicles assembled in China can access financial incentives (Allianz Research, 2023); China thus adopts a protectionist policy that tries to include incentives aimed at achieving increasing levels of technological excellence. The combined effect of strict protectionism and pressure on producers to raise the technological levels of electric vehicles has resulted in Chinese native brands capturing over 85% of the electric vehicle market by early 2024 (see Figure 4).

Incentives are paid directly to consumers in the form of a refund upon the purchase of vehicles included in a list prepared annually by the ministry and are parameterized against the vehicle's efficiency levels with a technological bar for accessing the incentives that is progressively raised (Li et al. 2018).

In the first phase (2009-12), incentives were introduced for hybrid vehicles that were increasing based on the vehicle's capacity to reduce fuel consumption; they ranged (with five brackets) from ¥50,000 (about €6,500) for vehicles guaranteeing more than 40% fuel savings to ¥4,000 (about €500) for vehicles guaranteeing between 5% and 10% fuel savings. The incentive reached ¥60,000 and ¥250,000, respectively, for full electric and hydrogen fuel cell cars.

In the following period (2013-15), incentives ceased to be parameterized to lower fuel consumption and were instead parameterized to the number of kilometers that can be traveled with a charge of electric energy. The incentive obviously increased with the mileage and was divided into three brackets: in 2013, they ranged from ¥35,000 (about €4,500) for full electric vehicles with a range between 80 and 150 km per charge to ¥60,000 (about €7,800) for vehicles with more than 250 km per charge. Plug-in hybrid vehicles (PHEVs) received ¥35,000 provided they could travel at least 50 km in full electric mode. The amounts of these incentives were reduced by percentages ranging from 27% to 43% between 2013 and 2017. The maximum reduction (43%) was for vehicles with the lowest range per charge.

For hydrogen vehicles, the incentive was set at ¥200,000 (about €26,000) for the entire 2013/17 horizon without mileage limitations.

In 2015, stricter control and reporting obligations were placed on car manufacturers receiving incentives, and more stringent standards were introduced on various technical aspects of the vehicles: battery energy density, maximum speed, average energy consumption per 100 km.

This policy of progressively raising the technological condition to access public incentives has contributed to the technological improvement of the fleet of electric vehicles circulating in China. Consider (Chu et al. 2023) that between 2012 and 2021, the average range of the fleet doubled to 391 km per charge, and in the same period, the average battery capacity and density increased by about 60% to 47 kWh and 141 Wh/kg in 2021, respectively. Also, the average electricity consumption per 100 km decreased by about 15% between 2017 and 2021, reaching 12.1 kWh/100 km.

There has been a 5-10% annual reduction in the monetary incentive amount between 2013 and 2015 and 20% between 2017/18 and 40%.

Chinese journalistic sources (Zhang 2023) citing Chinese ministerial sources estimate the total state subsidy expenditure for electric car demand at about ¥150 billion (about €19 billion), which, adding provincial subsidies, reaches ¥200 billion (about €26 billion). This is certainly a significant sum, but in relation to the size of the economy, it is not so important: it is about 0.16% of the Chinese GDP in 2022. For example, in Germany, cumulative incentive spending would be around €9.5 billion (about 0.5% of German GDP in 2022).

Non-Financial Incentives

Non-monetary incentives are concentrated in specific areas of the country and are structured to provide progressive regulation. Keep in mind that initially policies to support the electrification of transportation were mainly motivated by the need to reduce pollution in major metropolises (primarily Beijing and Shanghai) and to contain China's dependence on imported oil (Ma et al. 2017 and Liu et al. 2023). Specifically, to reduce the dramatic pollution problems, quantitative limits on the registration of new ICEs vehicles were introduced: the number of new license plates issued was limited by using auction or lottery mechanisms for license plate allocation. Restrictions were also introduced regarding the days ("alternate plates") and times when circulation is allowed in the most congested urban areas. Electric vehicles are always exempt from restrictions on license plate issuance and circulation. The registration of hybrid vehicles is subject to less stringent rationing than ICEs vehicles. In some cities, electric vehicles can also use bus lanes, and on some highway sections, they are toll-free. All the measures mentioned here (monetary and non-monetary) allow a "fine regulation," for example, the number of new plates for internal combustion vehicles can be varied from year to year, even based on a predetermined time profile.

Regional governments with the greatest success, like Shenzhen, have acted decisively not only in the electrification of public transport vehicles but also concerning logistics chains (De Podestà et al. 2023): i) sales of diesel light trucks have been prohibited; ii) "green logistic zones" have been created in urban centers where only electric vehicles (PHEV and BEV) can enter; iii) electric vehicles are allowed to circulate on roads reserved for public transport; iv) regional purchase incentives; v) operational subsidies for fleets with at least 100 electric vehicles. As a result, a competitive advantage has been created for logistics chains that have electrified their fleet.

An important factor for the spread of electric cars is obviously the development of charging points: at the end of 2021 (Chu et al. 2023), there were about 1,150,000 public charging points in China, about 65% of the global total; the figure is consistent with the estimate by the IEA for 2021 (about 1.2 million). A significant 41% of these public charging points were DC with high-speed charging (the highest percentage in the world). At the end of 2021, there were also 1.5 million private charging points. Liu et al. (2023) report an even higher number: a total of 1,680,000 charging points, of which 807,000 are public (one charging point for every three electric vehicles circulating at the end of 2020).

Between 2015 and 2021, the number of charging stations increased 18 times in China, four times in the EU, and 2.5 times in the USA (based on IEA data). It is estimated that at the end of 2023, there were about 2.7 million installed charging stations in China (Nikkei Asia 8/2/2024).

A recent World Bank study (Li et al. 2020) focuses on the period 2015-2018 and estimates that in China, an increase of 1,000 charging points has an effect equivalent to a purchase subsidy of ¥12,700 (about €1,600) in promoting electric vehicle sales. Considering that the study estimates that demand-side incentive policies have determined 55% (or 561,495 vehicles) of the total number of electric vehicles sold, against public spending of ¥55 billion (about €7 billion) in the period considered, the study estimates that an average public expenditure of ¥98,000 is associated with each electric vehicle purchase.

3. Some considerations about the European approach to transition (also in comparison with Chinese policies).

3.1 The Conditions for Technological Neutrality

When discussing "technological neutrality," we refer to the possibility of achieving environmental sustainability goals by a plurality of technological solutions. Specifically, this means being able to reduce the impact of polluting and climate-altering emissions (particularly CO2) not only by focusing on the electrification of engines but also by using synthetic fuels (e-fuels), biofuels, and hydrogen engines (fuel cells or hydrogen ICEs).

The possibility of having true technological neutrality also depends on the formulation of the objectives: given the need to safeguard the environment, for example, if the target contained in the legal standard is to have zero tailpipe emissions, the purely electric vehicle has no rivals and sidelines, for example, synthetic fuels obtained from green H2 and CO2 absorbed from the atmosphere (then re-emitted but with a zero balance). These types of fuels ensure that no additional CO2 is emitted into the atmosphere but generate tailpipe emissions.

However, the target set in the regulations is "theoretical": the energy we use to recharge the batteries is largely produced worldwide from thermal power plants using fossil fuels, making the goal of zero tailpipe emissions fictitious as it shifts emissions from the vehicle to the power plants. While it is true that power plants can be optimized in terms of efficiency and emissions, it is equally true that coal is still widely used globally (including in Europe) and that there are significant energy losses along the electricity distribution lines.

Thus, we could achieve the target of zero emissions if and only if all the energy used to power electric cars came from renewable sources. Here, we face the availability of "clean" energy; the honest question that needs answering is "when" and "how much" will we have enough?

An exhaustive discussion of this topic is beyond the scope of this work, but it seems useful to provide some summary elements to frame the topic of automotive electrification in a broader context. In this regard, the targets set in the National Integrated Energy and Climate Plan (PNIEC June 2024) show that the slopes of the curves related to the share of production from renewables change dramatically compared to historical trends. Even assuming discontinuities related to the injection of economic and technical resources, it is legitimate to doubt that all the planned actions will be effectively realized within the expected timeframes, given the amount of investments involved, the need to draft definitive projects, and to comply with all necessary administrative procedures.

Regarding our country, it is important to remember some structural weaknesses related to both electricity production and the electric vehicle charging infrastructure. Considering that a large part of the approximately 300 TWh of electricity produced in Italy still comes from thermal sources, it is essential to significantly increase the share produced from renewable sources. Indeed, today, 70.2% of electricity production in Italy comes from thermoelectric power and 7.2%, 9.9%, 2.1% and 10.7% from wind, photovoltaic, geothermal and hydropower, respectively (source: Terna)

Although May 2024 recorded the highest ever production from renewable sources, thanks to the growing contribution from photovoltaics, the road ahead is still long: renewable sources account for about 52.5% of current national consumption of electricity.

The results currently obtained are, however, very far from the objectives announced in the PNIEC: for example, the share of energy from renewable sources in transport and heating/cooling should increase from approximately 8.2% and 20.2% to 30.7% and 36.7% respectively by 2030 (Source: GSE Gestore Servizi Energetici, 2023).

When talking about technological neutrality, the fundamental condition remains the production of electricity from renewable sources. Only the adequate availability of such energy will make the objectives of reducing polluting emissions consistent and achievable (Figure 7). Moreover, a comparative environmental impact assessment between the construction and disposal of an ICE vehicle and a battery electric vehicle should also be considered.

3.2 Is the Path to the Electric Car Realistic and Sustainable?

The path outlined by the EU appears arduous and sets a significant risk of compromising the health of a very important industrial sector and of imposing high social costs as the transition involves a significant contraction of overall employment in the automotive sector, and consumers are required to pay high prices for the purchase of an electric vehicle in a period of modest economic growth.

Day by day, the critical issues related to the availability of raw materials, mostly located outside European borders, the development and production costs that make electric cars inaccessible to the mass of consumers, the non-extensive charging network, the considerable charging times, etc., emerge. For instance, if we think of electrifying heavy transport vehicles, we would need a dedicated charging network for them, both for the energy densities involved and for the space needed for prolonged stops.

The points mentioned above are not immediately solvable, so much so that major European manufacturers are seeking alliances and joint ventures with raw material producers and strategic agreements between manufacturers to produce electric cars at lower costs. But this requires time and the commitment of significant resources: it is conceivable that a shift in timelines and a real openness to different technologies (a potentially different solution for each context) will be very likely.

In the early months of 2024, we are witnessing negative reaction signals in the electric vehicle market: the European consumer, especially in the absence of strong incentives, does not seem very inclined to purchase purely electric cars. For example, the share of electric vehicles in total new vehicle sales in Germany dropped from 15.7% in February 2023 to 12.6% in February 2024, while the share of PHEVs remained stable around 7%.

We believe that the market share of hybrid vehicles is destined to increase and that the decline of thermal engines, especially gasoline ones, will be slower than previously predicted by major manufacturers. It is no coincidence that several major automakers are revising their strategic development roadmaps, postponing some investments in electric propulsion and extending the life of thermal engines; in particular, GM, Ford, and Daimler-Benz have recently announced a slowdown in their transition process towards electric vehicles and an extension of the timeline for the production of ICE vehicles.

In our opinion, Europe has not definitively lost the game to China on the issue of electric mobility, but it must regain technological leadership, which is currently in question, and the trust of Europeans. We believe that a thorough and non-ideological review of the transition strategy is needed, setting goals that must be: i) challenging but achievable; ii) compatible with effective technological neutrality and open to a plurality of solutions; iii) socially and industrially sustainable; iv) realistically aligned with geopolitical constraints: developing "WITH" and not "AGAINST" policies with patience and foresight. A correct political and technological positioning would allow equal comparisons with the USA and China with relational setups that ensure the respect of mutual interests.

Identifying fields where it is possible to maintain leadership and where there is adequate political will to do so. For example, think of autonomous driving, the ethical use of artificial intelligence, the development of the circular economy resulting from the recovery of all components of an electric vehicle...

In Europe, public procurement has played a marginal role; this trend must change in the coming years. The old European rules (Euro 1, Euro 2...; Euro 6) lent themselves to a gradual and differentiated interpretation: the technological target was progressively raised, encouraging European manufacturers to reach absolute excellence levels; these rules combined a ban on the sale of new vehicles with characteristics below a certain threshold with the possibility of subsequently selectively and modifiable limiting the circulation of vehicles based on their pollution level. In particular, the extension of restrictions was gradable with respect to local specificities: mayors of large cities can ban the circulation of vehicles at certain times, certain days, certain areas. Naturally, even in Europe - under current legislation - local administrators will be able to selectively regulate the circulation of ICE vehicles, but the total uncertainty in which they will operate today poses great difficulties for consumer choices with the possible paradoxical outcome of encouraging consumerist forms and, conversely, a slowdown in the renewal of the car fleet.

In China, administrative restriction on the circulation and sale of ICEs has been gradually introduced for years, leveraging not only bans but also incentives and disincentives. Conversely, in Europe, the restriction on the circulation of non-electric vehicles is minimal today and - under current legislation - is not even planned after 2035. Conversely, a sudden and total ban on the *sale* of ICEs is foreseen, which takes effect at midnight on December 31, 2029, and 2034 for diesel and gasoline cars, respectively. This European policy aims not at reducing local pollution but at reducing CO2 globally and therefore inevitably applies simultaneously to all EU countries and in large cities as in small towns. There remains great uncertainty about the restrictions on the circulation of ICE and PHEV vehicles after 2030 and 2035.

In Europe, the definition of an electric vehicle deserving of incentives should be technically more detailed and modified over time. For example, following the Chinese model in terms of minimum km of range in full electric and battery energy efficiency.

The redistributive mechanisms determined by carbon neutrality policies are enormous: consider that between 2018 and 2022, Tesla sold carbon credits worth a total of $4.8 billion, significantly contributing to its profits. For example, in the second quarter of 2021, against profits of $1.1 billion, revenues from the sale of carbon credits amounted to $350 million; over the entire 2021, sales of carbon credits accounted for 3% of total revenues. For Tesla, these revenues obviously come with enormous costs for traditional automakers: for example, between 2019 and 2021, the Fiat Chrysler group (since January 2021 Stellantis) spent $2.4 billion to buy carbon credits from Tesla. These costs for traditional automakers resulting from European and US regulations have caused a massive transfer of resources from consumers who bought traditional vehicles, workers of traditional groups, and shareholders to Tesla's consumers, employees, and shareholders.

In many respects, this situation creates distortive effects on the market structure, more hidden than the use of public resources derived from general taxation to finance the purchase of electric vehicles by consumers and/or to directly subsidize the production of electric vehicles.

3.4 A Fully Electric Future for Automotive?

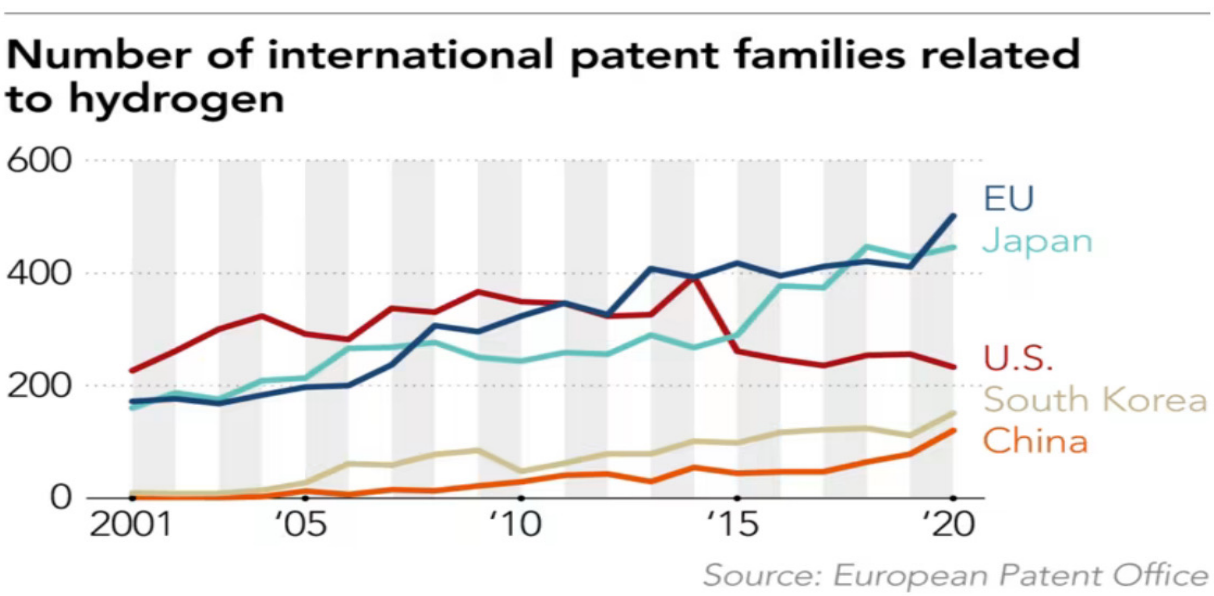
In no country electric cars seem to has definitively won the market challenge and a commitment to prohibit ICE engines from 2035 has only been assumed in the European Union and California. We believe it is necessary to reflect secularly on the possibility of having a 100% electric automotive sector and to fight the growing ideological component of the debate.

The following arguments lead us not to believe in the possibility of a 100% electric automotive sector by 2035:

- Too much delay and too many difficulties in installing charging stations; the number of public charging stations in the national territory is about 50,000 at the end of last year. Assuming, as set in the PNIEC 2024, to have 43 million pure electric vehicles (BEV) in 2030 and assuming one charging station for every 10 vehicles (a target set, for example, by France in its strategic plan), it follows the need to decuple the current number in a short period; something far from guaranteed. Another potentially relevant aspect from the perspective of social equity is that the price of electricity at the charging station is significantly higher than that paid at home.
- MotusE estimates that at the end of 2023 there were approximately 50,700 charging points in Italy (of which 43,564 with power less than 50kW, 4,579 with power between 50 and 149kW and only 2,535 with power greater than 150kW. 58% of these charging points were in the North of the country, 19% in the center and 23% in the South and on the islands. There were 932 charging points on the motorway (at least one service area out of 3). The number of charging points for every 100 BEVs was 23 in Italy while in France, Germany and the UK they was 14, 10 and 10 respectively.
- The above considerations further reinforce the need for a pragmatic approach to avoid that hardly achievable goals could trigger processes of inefficient allocation of investments and resources across the entire value chain, from vehicle manufacturers to their entire supply chain.
- "Bottlenecks" in the availability of rare earths to build batteries.
- Difficulty in reaching the capacity to produce European vehicles at sufficiently low prices within a reasonable timeframe.

- The objective of achieving complete technological neutrality (see above) requires time.
- The car fleet in many European countries is still extremely old and therefore inadequate both in terms of pollutant emissions and CO2 emissions. In Italy, the car fleet is about 40 million vehicles with an average age of 12.5 years (UNRAE). It is impossible today to produce (and place with consumers) millions of electric vehicles; it seems evident that a virtuous replacement of old polluting vehicles must also go through the use of small and medium power Euro 6 and 7 internal combustion engines. It is therefore appropriate to ensure a sufficiently high share of the circulating fleet at Euro 6 and 7 levels, also allowing European manufacturers to still exploit technologies and plants of absolute excellence.
- Electricity production from renewable and nuclear sources is still insufficient.
- Internal combustion engines directly fueled with H2 or Fuel Cells could cover a significant part of the mobility needs (especially heavy trucks), and Europe could play a leading role given the competencies it is developing on the topic (see Figure 5).

Fig.5 Number of international patents related to hydrogen



From an industrial policy perspective, we also note that an additional advantage of having a plurality of technological solutions is that it would eliminate the "technological bottleneck" represented today by the mandatory electric path, forcing many companies to focus on the same products, with competition more about survival than normal market dynamics excluding less efficient companies. The risk of this competition imposed from above is losing valuable European industrial excellences forever, which instead, with a more gradual and plural transition, could evolve with great success. A "plural" approach may result in fewer economies of scale in the short term, but in the medium-long term, exploring multiple technological alternatives can bring benefits to both consumers and businesses.

4. Italy: What to Do? Some Proposals

As is well known, the automotive industry has always had an important presence in Italy, contributing to economic development by generating technological spillovers to other sectors. As shown in Table 1, over the past 25 years, despite an increase of about 30 million in global passenger car production, Europe has lost about 5 million vehicles, NAFTA almost 4.6 million, while Japan maintains production volumes. As we have seen, it is China that enormously increases its production (by over 25 million). Within the European framework, Italy and France lose the largest shares (-61.4% and -60%, respectively), while Germany experiences more contained declines (-23.2%).

Table 1: Production of passenger cars

	1998	**2007**	**2013**	**2023**	**% Δ 98/23**	**% Δ 98/07**	**% Δ 07/23**	**% Δ 13/23**	**Absolute Δ 98/23**
EUROPE*	16.695.610	19.331.225	17.383.144	15.449.729	-7,5	1,6	-20,1	-11,1	-1.245.881
EU**	14.464.448	14.427.667	11.341.479	9.551.152	-34,0	0,0	-33,8	-15,8	-4.913.296
France	2.558.231	2.550.869	1.458.000	1.026.690	-59,9	0,0	-59,8	-29,6	-1.531.541
Germany	5.348.115	5.709.139	5.439.904	4.109.371	-23,2	0,7	-28,0	-24,5	-1.238.744
Italy	1.402.382	910.860	388.465	541.953	-61,4	-3,5	-40,5	39,5	-860.429
NAFTA	7.629.569	6.475.498	7.106.013	3.025.512	-60,3	-1,5	-53,3	-57,4	-4.604.057
USA	5.554.373	3.924.268	4.368.835	1.745.171	-68,6	-2,9	-55,5	-60,1	-3.809.202
China	507.103	6.381.116	18.085.213	26.123.757	5051,6	115,8	309,4	44,4	25.616.654
Japan	8.055.763	9.944.637	8.189.323	7.765.428	-3,6	2,3	-21,9	-5,2	-290.335
S. Korea	1.625.125	3.723.482	4.122.604	3.908.747	140,5	12,9	5,0	-5,2	2.283.622
WORLD	37.262.942	53.049.391	65.462.496	68.020.264	82,5	4,2	28,2	3,9	30.757.322

* EU15 + Uk + new East Countries that entered EU + Turkey; **EU15 + UK

Source: our elaboration on OICA data

These reductions in production volumes have therefore heavily impacted the supply chains, particularly the Italian one.

To contribute to the debate, we make the following considerations and proposals.

- As is well known, our manufacturing fabric is mainly composed of SMEs and lacks indigenous "technological tugboats," i.e., large companies with recognized technological leadership in their sectors capable of "pulling" the development of the supply chain. This means that the pull in the development of new products and processes must come from a stronger integration into global value chains: being suppliers to the most important German and French automakers is no longer enough (Table 2).

Table 2: % of world production of passenger cars

	1998	2007	2023
EUROPE*	44,8	36,4	22,7
EU**	38,8	27,2	14,0
France	6,9	4,8	1,5
Germany	14,4	10,8	6,0
Italy	3,8	1,7	0,8
NAFTA	20,5	12,2	4,4
USA	14,9	7,4	2,6
China	1,4	12,0	38,4
Japan	21,6	18,7	11,4
S. Korea	4,4	7,0	5,7
WORLD	100	100	100

* EU15 + Uk + new East Countries that entered EU + Turkey
**EU15 + UK

Source: our elaboration on OICA data

- The ongoing transformations are shifting technological leadership towards China (see the previous Table). It is necessary to know how to interact and operate even with the new emerging subjects; we imagine that China will further develop a "Local for Local" policy that will lead Chinese manufacturers to have factories in various European countries. Europe will continue to represent an important technological interlocutor and a very significant market. Thus, there is the opportunity to integrate the excellent capabilities of our companies into these new supply chains, also transforming current products to intercept new needs. It will be the task of politics, businesses, and social partners to ensure that this development occurs with the utmost respect for economic, social, and ethical values that are not negotiable.

- Our country has unique characteristics in terms of creativity of our entrepreneurs, technicians, and workers. This can be a winning card to place our companies in the overall global business. The long experience in the automotive sector, the presence of technological districts, the excellent quality of our productions, and the overall reliability of our companies can make our country very attractive for direct foreign investments. We can "invent" new products and processes and transform "Made in Italy" into "Invented & Made in Italy," avoiding Italy becoming a place of poor manufacturing.
- After the introduction of 100% tariffs in the USA and those proposed by the European Commission (see note 3), trade tensions between Western countries and China in the automotive sector risk degenerating. It is therefore worth reflecting on whether to pursue an escalation logic or to seek mutually beneficial solutions. It is not an easy task, but a deep, systematic, and precise analysis of the value chain can offer opportunities for collaboration rather than confrontation.
- The challenges listed above, however, require overcoming some important constraints. First of all, we need to push for the dimensional growth of our companies: the ongoing transformations require significant investments in R&D, substantial financial and human resources, the ability to develop international relations, and solid governance: these are necessary conditions to be "in the game." Reaching a minimum critical threshold, both in terms of knowledge and capitalization, becomes a fundamental requirement for the Italian manufacturing; the risk is to remain on the margins of the great ongoing technological transformations, surviving by settling for low value-added productions with low profitability and low wages. The problem of dimensional growth is not easy to solve: entrepreneurs have understandable difficulties in sharing experiences, efforts, and successes achieved over the years, even though, as evidenced by a recent Federmeccanica study (2024), the propensity to share in clusters, universities, etc., has increased.

  A more organic effort would be needed, involving both the business system and the willingness and support of public institutions. This theme naturally connects to the issue of generational transition underway in many small and medium Italian companies that should urgently open up to managerial governance and a growth scenario through aggregations.
- Federmeccanica has been emphasizing for long the need for a strategic vision of the entire country system and the need for questioning about what the national manufacturing vocation should be. In this sense, it is worth recalling the work done by Federmeccanica and the Trade Unions within the

automotive working group (Osservatorio automotive 2023). In this study, industrial and strategic comparisons with other European countries were made, and some fields of greater attention were identified. In recent years, economic policy has sometimes proven counterproductive, as incentives - primarily designed to support the demand for electric vehicles - have in fact mostly supported new generation hybrid and internal combustion vehicles. Thus, we have favored the partial renewal of the circulating car fleet but have not given sufficient stimuli to the technological evolution of the European car. This deserves a deep discussion that does not seem to be happening today.
A country like ours, important in the automotive supply chain, has an interest in having a plurality of interlocutors.

- Opening up to effective technological neutrality could provide significant support in identifying a national vocation: Italy, for example, could become a hub for producing green H2 and, consequently, e-fuels; our country could also have a role in the circular economy and recycling. The great challenge lies in intelligently and broadly connecting the various territorial projects. As also hoped by Luca de Meo, a European policy is needed that favors the transition from "electric monotheism" to the "bouquet" of technological neutrality.

We believe that some trends for the future can be outlined.

- The technological and cost supremacy of Chinese electric cars will continue: the exploitation of enormous economies of scale, easy access to essential raw materials, and a now demonstrated innovative capacity constitute decisive competitive factors. It seems difficult for Europeans to conquer a market leadership in the electric car sector in the near future.
- The trade war between the USA and China seems destined to continue; the European market will therefore become increasingly strategic for Chinese manufacturers, who have a growing excess production capacity. The commercial pressure from the Chinese automotive sector will become more aggressive, creating threats but also opportunities for collaboration.
  The interdependencies with China in the automotive sector are such that the hypothesis of a trade war would be devastating for everyone. Negotiations must be conducted with great firmness but also with great realism, even to build strategic alliances.
- Europe should plan a less drastic transition towards electric vehicles, allowing for an important role for low-energy-consuming hybrid vehicles and for vehicles developing other technologies (e.g., hydrogen, bio-fuel...). This, among other things, could allow for the creation and maintenance of technological leadership in some fields.

- Finally, but the issue seems to us of utmost importance, we believe that Europe should carefully evaluate the implications of a regulatory approach that, by setting limits in terms of emission density at the tailpipe and not absolute emissions, has penalized the European production of light and less polluting vehicles, favoring heavy, fast, and expensive vehicles (see Pardi's 2022). Absolute emission limits could enhance the role of PHEVs in the energy transition of the coming decades.

The transition to sustainable mobility must therefore offer a chance to rebalance this scenario: true technological neutrality is needed, correct incentives for producing low-pollution vehicles, and the ability to establish strategic alliances with the major global players.

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