UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

MASTER'S THESIS

THE COMPETITIVENESS OF THE EUROPEAN AND SLOVENIAN AUTOMOTIVE INDUSTRY IN THE CONTEXT OF GREEN TRANSITION

Ljubljana, April 2025 MAJA ŽELEZNIKAR

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ABSTRACT

This master's thesis examines the competitiveness of the European and Slovenian automotive industries, comparing them to global leaders China and the United States. The analysis combines statistical data with an empirical study based on in-depth interviews with industry experts. Findings show Europe is losing its competitive edge in several areas and facing various challenges, while Slovenia, as a smaller economy, remains highly dependent on European decisions. Meanwhile, China is strengthening its dominance in the global automotive industry, exerting greater influence on international markets. Consequently, Europe faces both internal obstacles and growing external pressures

KEY WORDS: Automotive industry, green transition, electric vehicles, competitiveness, technology, supply chain

SUSTAINABLE DEVELOPMENT GOALS

POVZETEK

Ta magistrska naloga preučuje konkurenčnost evropske in slovenske avtomobilske industrije ter ju primerja z globalnima velesilama, Kitajsko in ZDA. Analiza združuje statistične podatke z empirično študijo, ki temelji na poglobljenih intervjujih s strokovnjaki iz industrije. Ugotovitve kažejo, da Evropa izgublja svojo konkurenčno prednost na več področjih in se sooča z različnimi izzivi, medtem ko Slovenija, kot manjše gospodarstvo, ostaja močno odvisna od evropskih odločitev. Hkrati Kitajska utrjuje svojo prevlado v globalni avtomobilski industriji ter vse bolj vpliva na mednarodne trge. Posledično se Evropa sooča tako z notranjimi ovirami kot z rastočimi zunanjimi pritiski.

KLJUČNE BESEDE: avtomobilska industrija, zeleni prehod, električna vozila, konkurenčnost, tehnologija, dobavna veriga

CILJI TRAJNOSTNEGA RAZVOJA

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AD – autonomous driving
BEV – battery electric vehicle
capex – capital expenditure
CO_2 – carbon dioxide
CRM – critical raw material
ETS – Emissions Trading System
EU –European Union
EV – electric vehicle
FCEV – fuel-cell electric vehicle
GDP – gross domestic product
GHG – green house gas
GWh – Gigawatt hour
ICE – internal combustion engine
IEA – International energy agency
IRA – Inflation reduction act
NEV – new electric vehicle
OEC – Observatory of economic complexity
OEM – Original equipment manufacturer
PHEV – plug-in hybrid electric vehicle
R&D – research & development
RoW – rest of world
UK – United Kingdom
US – United States

1 INTRODUCTION

Over the past two decades, the automotive value chain has experienced significant regional shifts, influenced by changing supply and demand patterns and the expansion of global value chains. The European automotive sector is facing growing competition from non-EU manufacturers (Stolfa et al., 2019). China has become a dominant global supplier and consumer, while the influence of the EU and the United States in the global automotive value chain has declined (Dechezleprêtre et al., 2023).

A major transformation in the industry has been the rise of electric vehicles (EVs), with Europe's transition primarily driven by EU sustainability targets (Nettekoven & Mualla, 2023). Although EU climate policies set ambitious goals for low-carbon transportation, the supply chain has struggled to keep pace, and the absence of a coordinated strategy has created significant challenges for the automotive sector (European Commission, 2024). The transition to EVs presents multiple obstacles, including high production costs, supply chain dependencies, and gaps in infrastructure (Richert & Dudek, 2023). EV production, especially battery manufacturing, is heavily dependent on materials predominantly controlled by China (Pardi, 2022), which benefits from a competitive edge due to its access to essential raw materials, large-scale battery production, and cost efficiency (Chen et al., 2024). This shift has resulted in job losses, market disruptions, and difficulties in balancing environmental objectives with economic sustainability (Pardi, 2022). These challenges also pose risks for Slovenian automotive suppliers, as 40 percent of them are directly linked to the German market, according to the Slovenian Automotive Cluster ACS (Kovačič, 2024).

The thesis aims to evaluate the competitive position of European automotive industry, focusing on Germany, Europe's economic powerhouse, and Slovenia, representing a smaller domestic market within the EU. These countries are compared to China, which is a rapidly emerging global player that significantly influences global supply chain dynamics, and the United States, a highly competitive market that has some of the most influential automotive companies, particularly in the EV segment. The research focuses on a few key research questions. It examines whether Europe is losing its competitive edge in the automotive industry and identifies the reasons behind this. It explores whether the European and Slovenian automotive industries are moving in the right direction. Additionally, it analyzes how green transition initiatives influence the success and competitiveness of the automotive sectors in Europe and Slovenia. Finally, it assesses how well Europe and Slovenia are positioned to adapt to the emerging trends shaping the future of the automotive industry.

Furthermore, the study evaluates whether the European and Slovenian automotive sectors are aligning with global industry trends and examines the impact of green transition initiatives on their competitiveness and overall success. The primary methodological approach employed is data analysis. Various aspects of the automotive sector were analyzed

using data from reputable sources and relevant databases and publications. The research focuses on key metrics that provide insights into the competitive positioning of different countries within the global automotive industry, including value added, trade performance, productivity, output and some other important indicators. Key metrics from the selected countries were used as a foundation to evaluate broader aspects of the automotive industry, including emerging trends, ongoing shifts and challenges. In addition to quantitative analysis, research was derived from a review of academic articles, industry reports, and specialized platforms. The second part of the thesis is based on an empirical analysis conducted through interviews with industry professionals. Additionally, the artificial intelligence tool ChatGPT was utilized to enhance grammatical accuracy and refine writing style.

One of the limitations was the lack of data, particularly for China, as well as gaps in sector-specific data for the EU and the United States. To maintain focus and clarity, the thesis does not specifically examine other key automotive players, such as Japan and South Korea, despite their strong global presence. While both nations have well-established automotive industries and leading manufacturers, they are less central to the specific scope of this study. Additionally, inconsistencies in industry classifications across sources and databases created challenges in data comparability. Since the data was originally expressed in different currencies, average yearly exchange rates from European Central Bank were applied to standardize all figures in euros, the currency of the primary countries under observation. Another constraint was the evolving nature of the automotive sector, shaped by geopolitical shifts and trade tensions. As a result, some data may do not reflect real-time developments. Events such as shifting global trade dynamics could further contribute to uncertainty in assessing long-term industry trends.

Master's thesis is structured into five chapters. After introduction, chapter two examines the current state and role of the global automotive industry, analyzing value added, trade, key performance indicators and major trends shaping the sector. The analysis focuses on the EU, especially Slovenia and Germany and compared them to China and the US. The following chapter explains the methodology employed in the research. Chapter four presents empirical findings from interviews with industry professionals, assessing the competitiveness of the Slovenian and European automotive sectors, the green transition, regulatory and policy impacts, supply chain challenges, and technological advancements. Finally, the last chapter concludes the thesis by summarizing key findings and answering research questions.

2 THE CURRENT STATE AND ROLE OF AUTOMOTIVE INDUSTRY

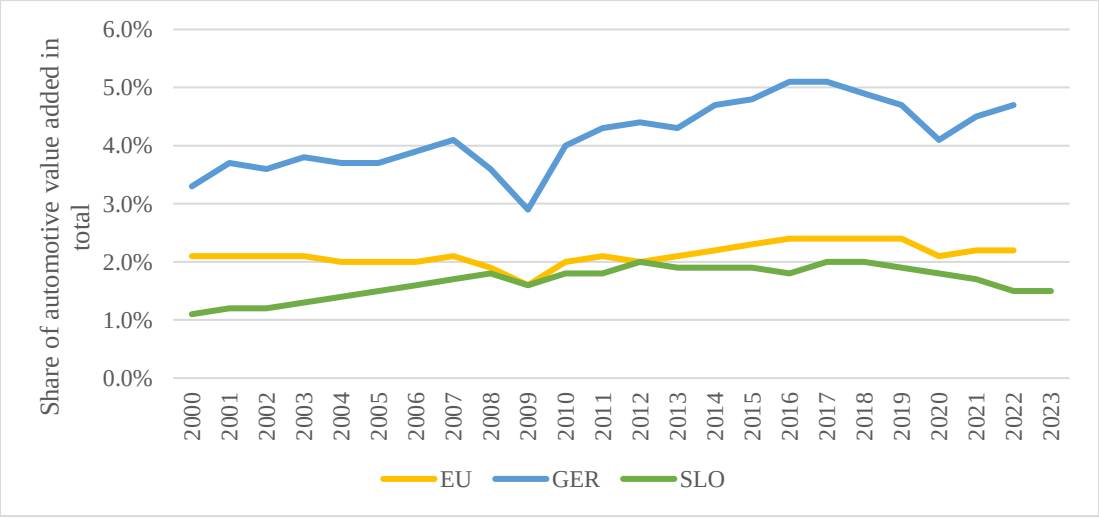
2.1 The role of automotive industry

2.1.1 Analysis of value added in automotive sector

The European automotive sector, encompassing road vehicles (including air-cushion vehicles) and other transport equipment, generated €320 billion value added in 2022, accounting for 2.2 percent of total as presented in Figure 1 and nearly 15 percent of all manufacturing value added. For context, manufacturing—historically the most significant economic activity in terms of value added across the European Union—contributed €2.16 trillion or 16.3 percent of total value added in 2023. The two other leading industries in the EU were wholesale and retail trade, including repair of motor vehicles and motorcycles, which generated €1.40 trillion, and real estate activities, which contributed €1.38 trillion. While the importance of the automotive industry has grown in recent years, it has yet to return to pre-2020 levels, when its share of total value added stood at 2.4 percent (Eurostat, 2024b).

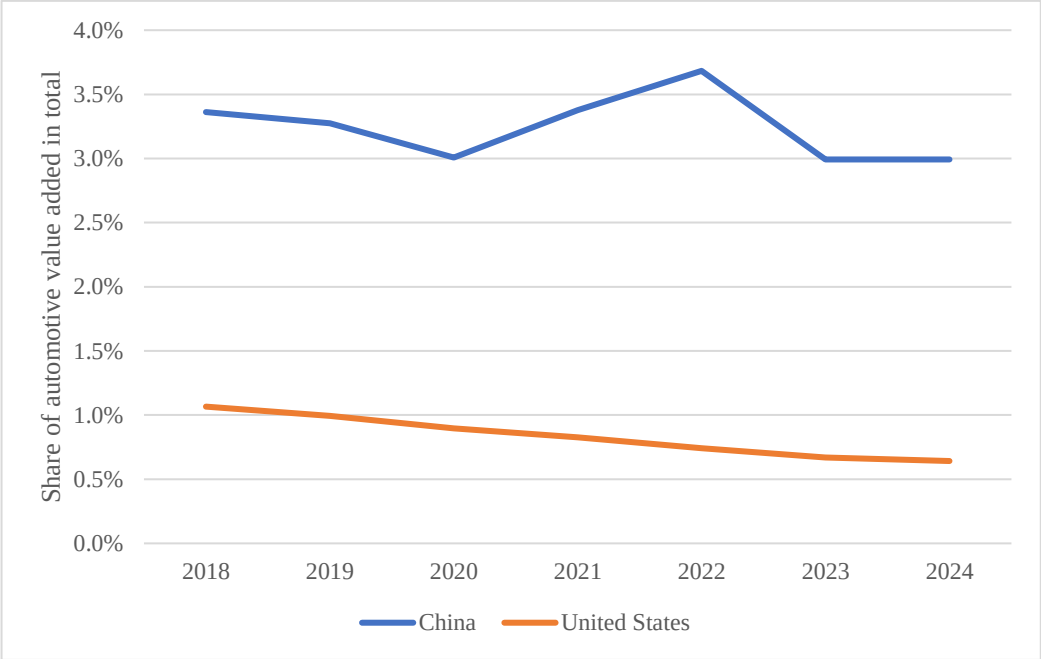
The largest contributor to the European Union's total value added is Germany (24 percent in 2023), which also accounts for more than half of the EU's automotive value added, significantly outpacing all other European countries. Other key contributors to the European automotive industry, including France, Italy, and Spain, collectively contribute less than half of Germany's total (Eurostat, 2024b).

Figure 1: Contribution of automotive sector to country's total value added from 2000-2023 (in %)



Source: Adapted from Eurostat (2024b).

Figure 2: Contribution of automotive sector to country's total value added for China and the US from 2018-2024 (in %)



Source: Adapted from Statista (n.d.-a), Statista (n.d.-d).

Germany's automotive sector has experienced impressive growth, with its value added more than doubling over the past two decades, growing from €74.7 billion in 2000 to €171.3 billion in 2022, but the growth since 2018 was more modest. After a decline in 2019 and 2020, it began to recover following the pandemic (Eurostat, 2024b). Its share in the national total value added has also risen, from 3.3 percent to 4.7 percent in the same period, highlighting the sector's growing economic significance. It's important to note that approximately 90 percent of the automotive sector's value added comes from road vehicles (Eurostat, 2024b), which will be the primary focus of the thesis.

In contrast, China achieved a 33 percent increase in automotive value added. However, it is worth noting that the observed period (2018–2024) is significantly shorter than that of the European countries due to data availability. Moreover, in absolute terms, China's automotive value added, growing from €298.4 billion in 2018 to €398.4 billion in 2024, now surpasses that of the entire European region. Similar to Germany, a significant majority of China's value added stems from road vehicles, accounting for 87 percent during this period. Additionally, Chinese automotive industry contributed 3 percent to nation's value added as shown in Figure 2, which is a notable decrease from year when it reached a peak at 3.7 percent (Statista, n.d.-a).

The United States reported somewhat comparable value-added figures for the automotive sector (data available from 2018–2024) compared to Germany; however, its industry has not matched the performance and growth seen in Germany. In 2018, the value added by the US

automotive sector stood at €186.4 billion but declined to €173 billion by 2024, a 7.2 percent decline. Furthermore, this sector contributes a very small proportion to the country's overall value added, accounting for just 0.7 percent of the total in 2024, down from 1.1 percent in 2018 (Statista, n.d.-d). Additionally, approximately 83 percent of this value-added originates from road vehicles. Overall, automotive industry accounts for about 10 percent of manufacturing value added (Statista, n.d.-d). But also, manufacturing in general plays a much smaller role in the US economy compared to European countries, contributing only 10.3 percent to the country's gross domestic product (GDP) in 2023. By contrast, other sectors, such as finance, insurance, real estate, rental, and leasing, were the primary drivers of value addition, contributing €5.27 trillion (20.7 percent of GDP). Professional and business services also made a significant impact, adding €3.23 trillion (13 percent of GDP) (Statista, 2024a; Statista, 2024b).

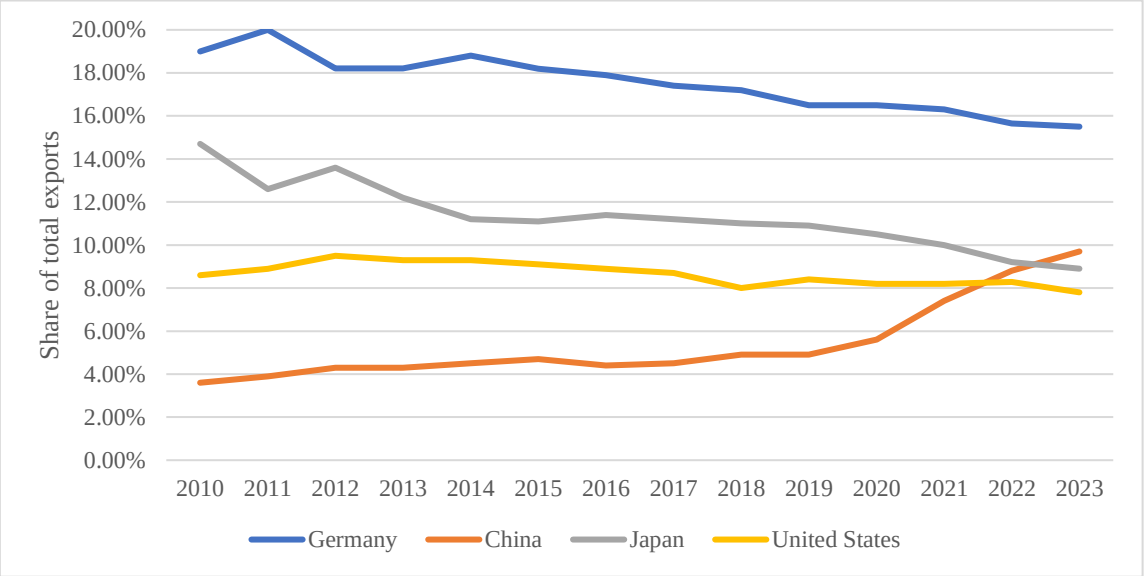
Similar to the United States, Slovenia's automotive sector has seen a decline in its share of automotive value-added. Slovenia actually ranks third in the EU in terms of the share of manufacturing value added, contributing 22 percent to its national total in 2023, but the automotive sector's contribution to total VA was only 1.5 percent in the same year—significantly down from its peak of 2 percent in 2017. The sector's share had been rising steadily since the early 2000s, peaking in 2017, but began to decline thereafter. In absolute terms, Slovenian automotive value added was €320 million in 2000 and peaked in 2019 at €828.3 million. However, following the pandemic, this figure dropped 30 percent, falling to €580 million in 2023. Notably, the majority of Slovenia's automotive value-added comes from road vehicles, a segment that has consistently accounted for more than 90 percent since the early 2000s (Eurostat, 2024b).

2.1.2 Trade analysis

Since road vehicles account for the majority of automotive value added, trade analysis focuses on this subsector. Cars, tractors, trucks & parts thereof (road vehicles), were the world's fourth most traded product in 2023, total exports were $1.89 trillion and the largest exporters were Germany, China, Japan, and the United States, which is illustrated in Figure 3. Germany's share fell from 18.6 percent in 2010 to 15.5 percent in 2023, while China's improved from 3.7 percent to 9.7 percent in the same period (OEC, 2025b).

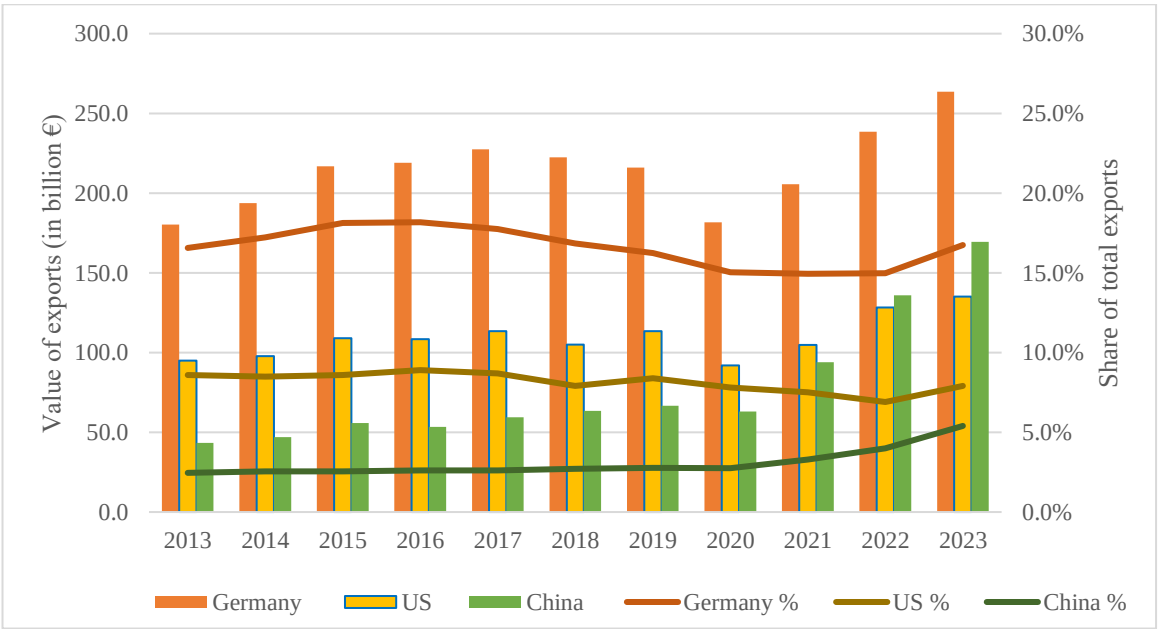
The road vehicle exports for Germany, China, and the United States are presented in Figure 4. Germany stands out for its consistent leadership in absolute export values, while China's rapid growth in both value and share shows its increasing global significance. Slovenia (shown seperately in Figure 5), despite its smaller scale, achieved strong proportional growth, particularly between 2013 and 2018, whereas the United States faced challenges in sustaining both relative and absolute export growth (Eurostat, 2024a; OEC, 2025b).

Figure 3: Share of global automotive exports (in %) for Germany, China, Japan, and the US from 2010 to 2023



Source: Adapted from OEC (2025b).

Figure 4: Road vehicle exports (in billion €) and their share in country's total exports (in %) from 2013-2023 for Germany, China and the US



Source: Adapted from Eurostat (2024a); OEC (2025c), OEC (2025f).

Germany consistently led in automotive exports, starting at €180.3 billion in 2013 and increasing to €263.6 billion in 2023, representing growth of over 46 percent. Its share of automotive exports within total exports peaked at 18.2 percent in 2016, declined to 14.9 percent in 2021, and rebounded to 16.7 percent in 2023 (Eurostat, 2024a). However, despite

this recovery, Germany's share of global automotive exports has been on a decline since reaching its peak of 19.3 percent in 2011, dropping to just 15.5 percent in 2023, reflecting a weakening of its global significance (OEC, 2025b). Half of the sector's exports were generated by motor cars, with 37 percent attributed to parts and accessories. The United States and China remained the largest markets for motor cars; however, exports to both countries declined in 2023. In contrast, the United Kingdom, the third-largest importer, experienced consistent growth in imports from 2021 onward (Eurostat, 2024a). The percentages of German road vehicle exports as well as imports to specific destinations are presented in Table 1.

Table 1: Shares of Germany's road vehicle exports and imports to/from China, Intra-EU, and the US in total road vehicle exports/imports from 2017 to 2023 (in %)

Destination	Import/Export	2017	2018	2019	2020	2021	2022	2023
China	Import	1.6	1.7	1.6	1.8	2.9	3.4	3.1
	Export	9.7	11.1	11.3	13.7	13.2	12.2	9.0
Intra- EU	Import	75.4	76.4	76.0	76.7	75.9	73.4	73.6
	Export	42.3	42.5	42.9	43.0	43.2	43.5	47.4
United States	Import	6.1	4.6	5.1	5.8	5.2	6.3	6.1
	Export	12.2	12.1	12.0	10.7	11.4	13.3	12.1

Source: Adapted from Eurostat (2024a).

Slovenia, while operating on a smaller scale, is notably reliant on automotive exports, which accounted for nearly one-fifth of the country's total exports—a higher proportion than in Germany. The Slovenian automotive sector plays a crucial role in European vehicle production, focusing on the supply of essential components and systems to top automakers while exporting to over 120 countries worldwide (SPIRIT Slovenia Business Development Agency, 2023). The country has gained global recognition for its expertise in manufacturing high-quality titanium exhaust systems for motorcycles, diesel cold-start mechanisms, and gas springs (SPIRIT Slovenia Business Development Agency, 2023).

Slovenia also recorded significant growth rate in the last 10 years. Its export values increased from €3.3 billion in 2013 to €9.2 billion in 2023, nearly tripling over the decade, which is depicted in Figure5 (Eurostat, 2024a). In 2023, Germany, France, and Croatia emerged as Slovenia's top export markets, representing 23 percent, 19 percent, and 10 percent of total exports, respectively (OEC, 2025e) Motor vehicles constituted 65 percent of the country's automotive exports, while parts and accessories made up 27 percent (SPIRIT Slovenia Business Development Agency, 2023).

Figure 5: Slovenian road vehicle imports and exports (in billion €) and their share in total (in %) from 2013-2023

Source: Adapted from Eurostat (2024a).

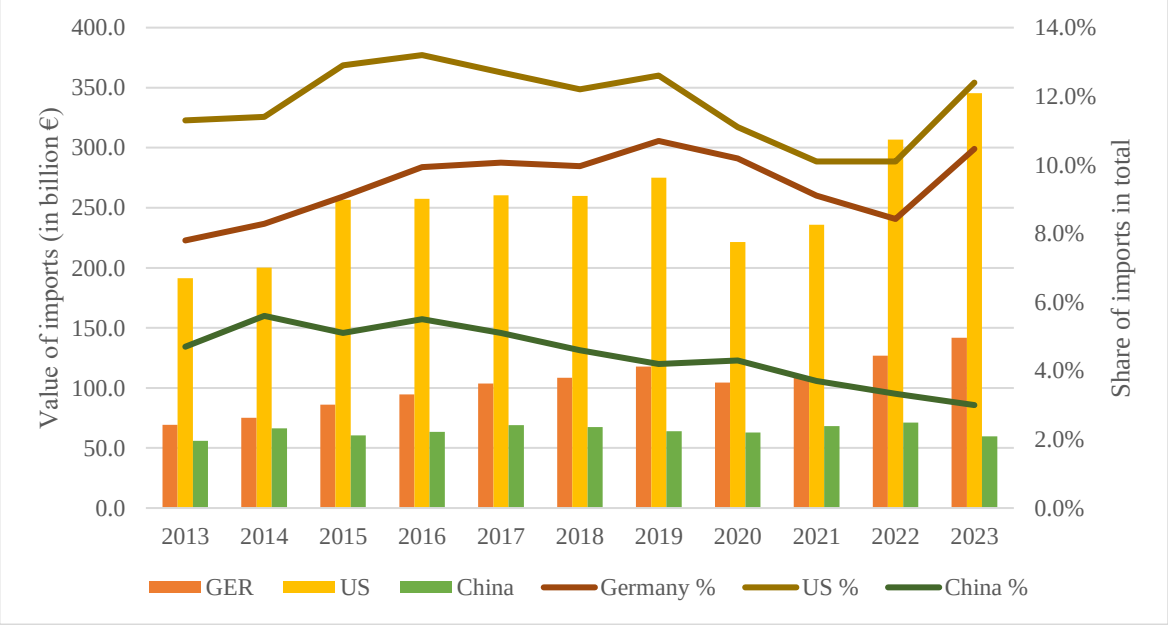
In contrast, the two non-European countries analyzed—China and the United States—show less reliance on automotive exports relative to their total exports. As previously analyzed, China has the highest automotive value added globally, yet its export volume does not fully align with this scale, which indicates its strong domestic demand. However, the data reveals significant absolute growth, particularly from 2020 onward. Starting at €43.3 billion in 2013, China's automotive exports experienced some fluctuations before accelerating in recent years, reaching €183 billion in 2023—a remarkable 291 percent increase over the period. Additionally, the share of road vehicle exports within China's total exports has grown steadily, which means that the automotive industry's importance to the country's economy is growing. Its share steadily rose from 2.5 percent in 2013 to 5.4 percent in 2023. A substantial share of this growth took place between 2022 and 2023, with a notable 35 percent increase. For context, China's largest export category in 2023 was electrical machinery and electronics, totaling €1 trillion—nearly one-third of the country's total export value. This was followed by machinery, electrical appliances, and parts, which accounted for 17 percent. Automotive exports, including cars, tractors, trucks, and parts, ranked as the third-largest category (OEC, 2025c).

In the last two decades, China has therefore become an increasingly important global player in road vehicle exports (OEC, 2025c). While it accounted for less than one percent of global exports in 2001, by 2023, it exported nearly 10 percent of global road vehicles, making it the second-largest exporter, surpassing both Japan and the US (OEC, 2025b). In 2023, the key export markets for Chinese cars included Russia, the United States, Mexico, and the United Kingdom. Notably, Russia accounted for 12.3 percent of China's car exports, which is an impressive 173 percent growth from just 4.5 percent the previous year (OEC, 2025c).

Although data for 2024 is not yet fully available, some sources suggest that China has become the world's leading car exporter, in terms of units. In total, China exported almost 5 million vehicles in 2023, including 1.2 million EVs (International Trade Council, 2024).

The United States displayed a more inconsistent trajectory with fluctuating export values. Unlike the other three countries, US automotive exports showed smaller growth of just 42 percent between 2013 and 2023, rising from €94.9 billion to €135.2 billion. Additionally, the US share of automotive exports within total exports steadily declined from 8.6 percent in 2012 to 6.9 percent, however, this decline could also be attributed to the fact that overall US exports grew at twice the rate of automotive exports in 2022. In 2023 the share increased to 7.9 percent. Furthermore, the US global share of automotive exports has been on a downward trend since 2012. In fact, the US reached its peak global export share in 1997, at 12.1 percent, but by 2023, this had decreased to 7.8 percent (OEC, 2025f). For reference, in terms of export value, the highest contribution in 2023 came from mineral fuels, mineral oils, and their distillation products ($348 billion), followed by machinery, mechanical appliances, and parts ($261 billion), and electrical machinery and electronics ($151 billion) (OEC, 2025f).

Figure 6: Road vehicle imports (in billion €) and their share in country's total exports (in %) from 2013-2023 for Germany, China and the US



Source: Adapted from Eurostat (2024a); OEC (2025c), OEC (2025e).

Data presented in Figure 6 highlight dynamics in road vehicle imports and their share in total imports, which differ slightly from export trends. The United States stands out as the leader in absolute import values, consistently reporting the highest figures among the four countries analyzed. However, the US share of global road vehicle imports has declined over

the past two decades. In 2000, the country accounted for 28 percent of global road vehicle imports, but this share decreased to 19.8 percent by 2023 (OEC, 2025b).

Starting at €191.3 billion in 2013, US road vehicle imports rose to €345.3 billion in 2023, an 81 percent increase. However, in 2020, imports dropped to €221.3 billion, due to global trade disruptions caused by the pandemic. Despite this setback, road vehicle imports surpassed pre-pandemic levels by 2022 (OEC, 2025f). Meanwhile, the share of road vehicle imports in total US imports rose from 11.3 percent in 2013 to 12.4 percent in 2023, highlighting an increasing reliance on imported vehicles. In 2023, the primary sourcing countries for US vehicle imports were Mexico, which supplied nearly a third of all vehicles, followed by Canada and Japan. South Korea ranked as the fourth-largest supplier, while Germany's share in US imports also saw an increase. In contrast, the US significantly reduced vehicle imports from China, dropping from 6.1 percent in 2022 to 4.4 percent in 2023 (OEC, 2025f).

Similarly to the US, Germany also consistently demonstrated robust growth in import values, starting at €69.4 billion in 2013 and more than doubling to €141.9 billion by 2023. Particularly imports of road vehicles from China surged from just €1.7 in 2017 to €4.4 billion in 2023, representing a growth of 159 percent over this period (Eurostat, 2024a). However, the largest suppliers in the past decade have been Czechia, France and Spain (OEC, 2025d). The share of road vehicle imports in total imports peaked at 10.7 percent in 2019 before dipping slightly during the disruptions of 2020 and 2021. By 2023, road vehicle share had rebounded to 10.5 percent (Eurostat, 2024a).

While automotive imports in Slovenia are smaller in absolute value, they hold significant proportional importance, as shown in Figure 5. Starting at €2.9 billion in 2013, its imports grew nearly threefold to €8.4 billion in 2023. Road vehicle imports therefore play an important role in Slovenia, accounting for 12.7 percent of total imports in 2023—higher than in the other analyzed countries. This reliance was even greater in 2017, reaching 17.2 percent (Eurostat, 2024a).

All four countries experienced a decline in imports in 2020 as the pandemic began, but China was the least affected, importing nearly as much as the previous year. Starting at €55 billion in 2013, Chinese import values peaked early at €65.9 billion in 2017, before declining during the pandemic. However, they rebounded to €68.4 billion in 2022. Despite the overall increase in import values from 2013 to 2022, the share of automotive imports within China's total imports decreased by 26 percent, reflecting a relative shift in the composition of imports (OEC, 2025c).

2.2 Performance comparison

2.2.1 Analysis of labour productivity

Table 2 and Figure 7 show comparative analysis of labour productivity, measured in thousand EUR per employee, across Germany, Slovenia, the United States and China from 2018 to 2024. The analysis reveals a general trend of declining productivity in the automotive sector. Notably, Germany, Slovenia, and the United States have experienced consistent declines since 2018, while China, initially demonstrating growth, began to experience a downturn in 2022 (Statista, n.d.-a; Statista, n.d.-b; Statista, n.d.-c; Statista, n.d.-d). These dynamics highlight that traditional leaders are facing challenges and emerging players like China displaying greater resilience until recently.

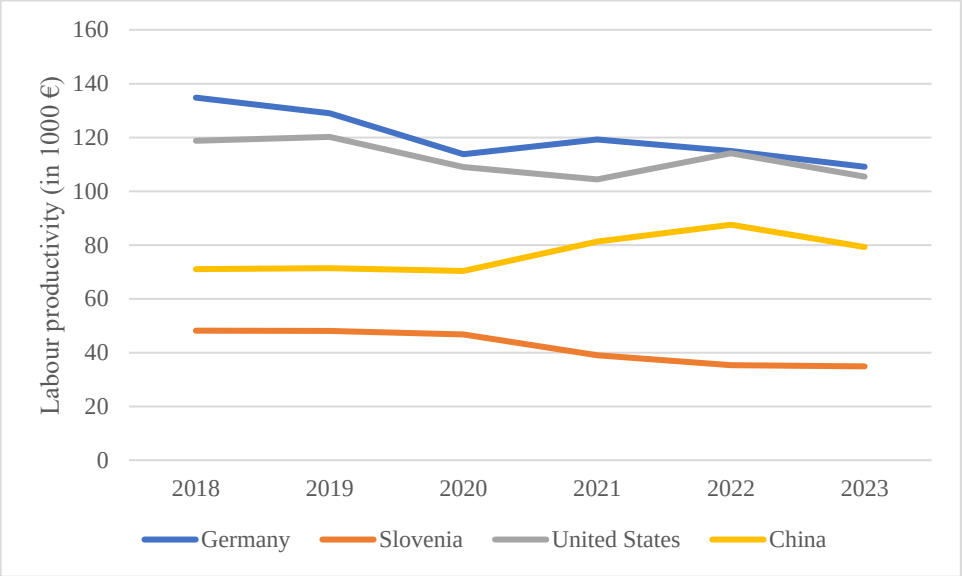
Table 2: Breakdown of labour productivity in automotive sector for Germany, Slovenia, the US and China from 2018-2024 (in 1000€)

		2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Germany	Automotive	**134.8**	**129**	**113.8**	**119.2**	**114.9**	**109.1**	**109.1**
	Road vehicles	140	131.6	117.6	123.4	118.3	113	113
	Other transport equipment	102.9	113.2	91.2	95.8	96.2	89.1	89.1
Slovenia	Automotive	**48.16**	**48.08**	**46.70**	**38.98**	**35.31**	**34.88**	**/**
	Road vehicles	49.16	48.94	46.27	37.96	34.36	32.92	/
	Other transport equipment	32.22	33.74	56.15	58.17	50.05	61.27	/
The United States	Automotive	**118.8**	**120.2**	**109**	**104.4**	**114.1**	**105.4**	**104.6**
	Road vehicles	163.8	165.9	150.7	142	154.8	140.4	139.3
	Other transport equipment	46.3	47.4	44.9	43.8	47.6	45.9	45.5
China	Automotive	**71.02**	**71.43**	**70.36**	**81.28**	**87.55**	**79.24**	**78.45**
	Road vehicles	80.65	80.88	79.74	92.09	99.36	89.61	88.93
	Other transport equipment	38.93	38.83	38.48	44.48	47.69	43.36	42.91

Note: Labour productivity is calculated as value added divided by the number of employees.

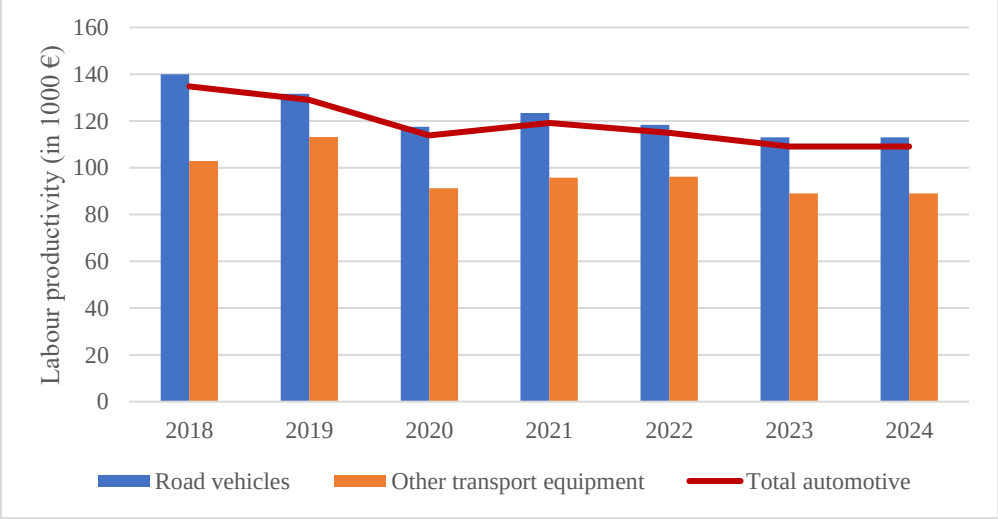
Source: Data for Slovenia adapted from SiStat (2025); data for other countries adapted from Statista (n.d.-a), Statista (n.d.-b), Statista (n.d.-d).

Figure 7: Labour productivity in automotive sector for Germany, Slovenia, United States and China from 2018-2024 in 1000€



Source: Adapted from Eurostat (2024a); SiStat (2025); Statista (n.d.-a), Statista (n.d.-b,, Statista (n.d.-d).

Figure 8: Comparison of labour productivity in German automotive sector by subsector from 2018-2024 (in 1000€)



Source: Adapted from Statista (n.d.-b).

As shown seperately in Figure 8, the German automotive sector recorded the highest labour productivity among the analyzed countries. However, it has experienced a significant decline, with overall automotive productivity falling by 19.1 percent, from €134.8 thousand per employee in 2018 to €109.1 thousand in 2024. Within the sector, road vehicles remain the dominant subsector, consistently displaying higher productivity compared to other

transport equipment. Nevertheless, both subsectors have faced declines, with road vehicle productivity dropping 19.3 percent, from €140 thousand in 2018 to €113 thousand in 2024. Nonetheless, automotive sector in Germany still has one of the highest labour productivities among manufacturing industries, only medical devices & products has higher productivity (data from 2018-2024) (Statista, n.d.-b).

Similarly, the United States has been experiencing a decline in labour productivity since 2018. While its total automotive productivity is lower than Germany's, the road vehicles subsector in the US exhibits notably higher productivity levels. For instance, road vehicle productivity peaked at €165.9 thousand in 2019 but fell 16 percent to €139.3 thousand by 2024. In contrast, the other transport equipment subsector shows much lower productivity, which drags down the overall figures for the automotive sector. Total automotive productivity in the US declined from €118.8 thousand in 2018 to €104.6 thousand in 2024, although the US managed to recover slightly in 2022 (Statista, n.d.-d).

Slovenia cannot be easily compared to the other three countries due to its significantly lower scale and productivity levels. The country's automotive industry is small, with only one original equipment manufacturer (OEM), yet has more than 100 suppliers and 600 sub-suppliers (SPIRIT Slovenia Business Development Agency, 2023). Slovenian automotive industry employed 16,825 people in 2023 (SiStat, 2025) and its peak labour productivity was €48.16 thousand per employee in 2018, which declined to €34.88 thousand in 2022. The road vehicles and other transport equipment subsectors exhibited opposite trends: while the other transport equipment subsector has been growing since 2018, the road vehicles sector has been in decline (Eurostat, 2024a; SiStat, 2025).

China presents a striking contrast to the other countries, as it initially exhibited strong growth in labour productivity in both road vehicles and other transport equipment. From 2018 to 2022, China's total automotive productivity rose by 23.3 percent, from €71.02 thousand to €87.55 thousand per employee, before declining to €78.45 thousand in 2024. Road vehicle and other transport equipment productivity followed the same pattern, increasing until 2022 and then falling thereafter. Despite this recent downturn, China remains the only country among the four where 2024 productivity levels are still higher than in 2018 (Statista, n.d.-a).

2.2.2 Analysis of manufacturing intensity

The total automotive industry category reveals a notable decline in manufacturing intensity (shown in Table 3 and Figure 9), which is calculated as output divided by GDP, across most countries from 2018 to 2024, particularly for Germany and the US. Germany, which saw a decrease of nearly 25 percent from 2018 to 2024, stands out for this contraction, while China has consistently maintained strong levels, despite some fluctuations. The road vehicles category mirrors this trend, with Germany and the US experiencing significant reductions, while China saw an increase in 2021 before a slight dip. Slovenia's production remained

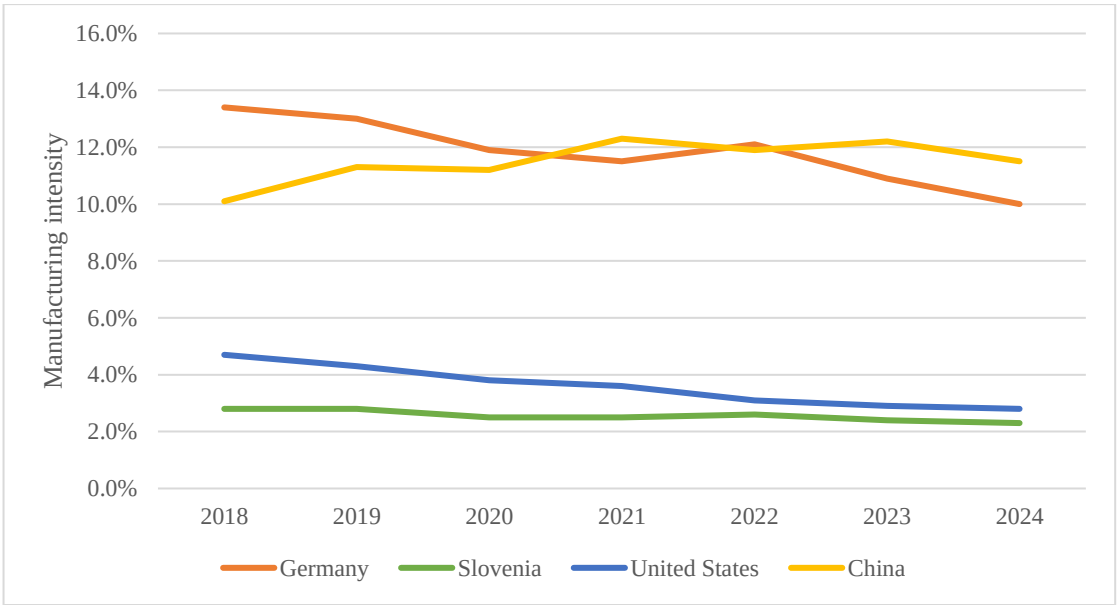
relatively stable but showed gradual declines. The other transport equipment category, in contrast, saw minimal change, especially in Slovenia, compared to the other categories, while the US faced a decline in this category as well (Statista, n.d.-a; Statista n.d.-b; Statista n.d.-c; Statista, n.d.-d).

Table 3: Manufacturing intensity (Output/GDP) in automotive and its subsectors by country from 2018-2024 (in %)

Category	Country	2018	2019	2020	2021	2022	2023	2024
Total automotive	Germany	13.4	13.0	11.9	11.5	12.1	10.9	10.0
	Slovenia	2.8	2.8	2.5	2.5	2.6	2.4	2.3
	US	4.7	4.3	3.8	3.6	3.1	2.9	2.8
	China	10.1	11.3	11.2	12.3	11.9	12.2	11.5
Road Vehicles	Germany	11.9	11.5	10.3	10.0	10.4	9.3	9.1
	Slovenia	2.7	2.6	2.4	2.4	2.5	2.3	2.2
	US	3.2	3.1	2.7	2.5	2.2	2.1	2.0
	China	8.9	9.9	9.8	10.8	10.4	10.6	10.1
Other Transport Equipment	Germany	1.4	1.5	1.6	1.5	1.7	1.6	1.5
	Slovenia	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	US	1.5	1.3	1.1	1.0	0.9	0.8	0.8
	China	1.3	1.4	1.4	1.5	1.5	1.5	1.4

Source: Adapted from Statista (n.d.-a), Statista (n.d.-b), Statista (n.d.-c), Statista (n.d.-d).

Figure 9: Manufacturing intensity (output/GDP) of automotive industry by country from 2018-2024 (in %)



Source: Adapted from Statista (n.d.-a), Statista (n.d.-b), Statista (n.d.-c), Statista (n.d.-d).

2.2.3 Analysis of output and sales

The global output value of the automotive sector in 2024 reached €5.6 trillion, reflecting growth from €4.8 trillion in 2018. Motor vehicles accounted for €4.7 trillion of this output, with China leading as the largest contributor, generating €1.9 trillion, or 37 percent of the total. Europe followed with €1.1 trillion in 2022, with Germany alone accounting for €440 billion, while the United States contributed around €600 billion. Collectively, these three regions accounted for 70 percent of the global automotive output value (Statista, n.d.-a; Statista, n.d.-b; Statista, n.d.-d).

In terms of produced units, global vehicle production between 2000 and 2023, presented in Table 4 and Figure 10, reveals significant changes in the automotive landscape, marked by China's rise and declines in traditional powerhouses like the EU and the US. Globally, production increased from 58.3 million vehicles in 2000 to 93.5 million in 2023, a growth of 60 percent. However, this growth was not evenly distributed, and many regions experienced stagnation or declines (OICA, n.d.-a).

Table 4: Comparison of vehicle production (in units) and growth (in %) by country for 2000 and 2023

Country/Region	2000 (units)	2023 (units)	Change (%)
European Union	18,276,937	15,300,000	-10.5
Germany	5,500,000	4,100,000	-25.8
Slovenia	122,949	153,172	24.6
United States	12,800,000	10,600,000	-17.2
China	2,100,000	30,200,000	1338
Total	58,300,000	93,500,000	6.0

Source: Adapted from OICA (n.d.-a).

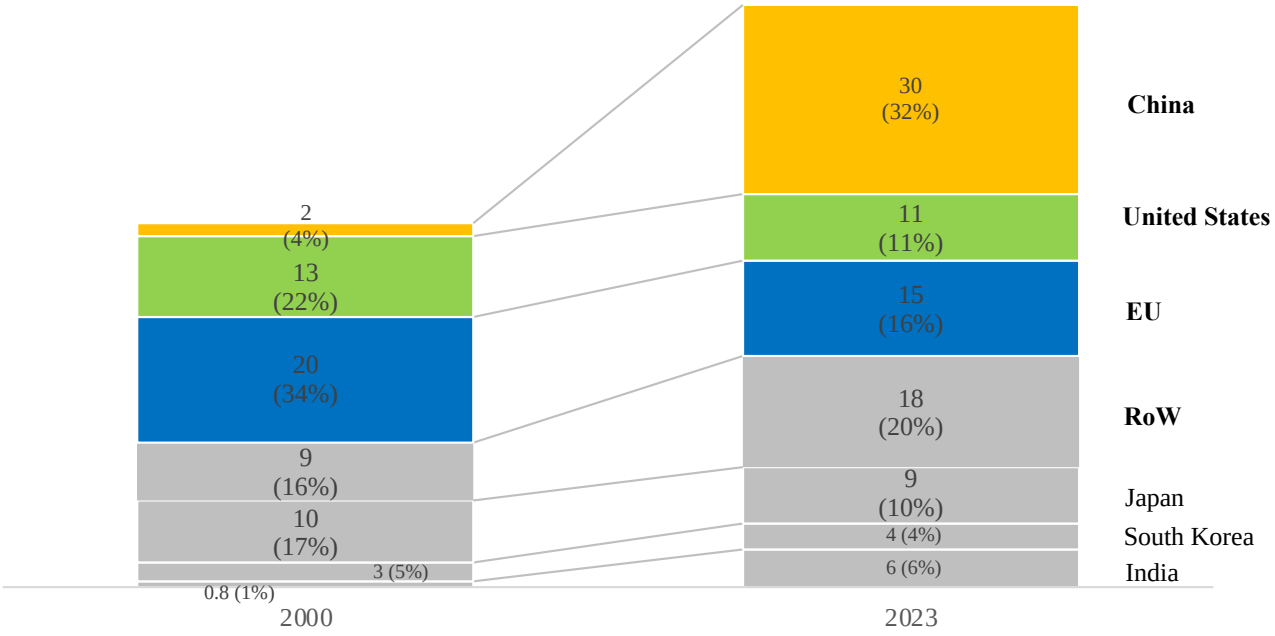
The EU28 (including UK) produced 18.3 million vehicles in 2000, but by 2023, this figure had declined to 15.3 million, marking a 10.5 percent decrease. Germany, as the EU's largest producer, experienced a more pronounced decline, with production falling from 5.5 million vehicles in 2000 to 4.1 million in 2023—a 25.8 percent drop. Notably, both the EU and Germany faced significant dips during the pandemic, with EU production reaching the lowest point at 12.9 million in 2021 and Germany at 3.1 million in the same year, before partial recoveries by 2023. Meanwhile Slovenia, a smaller EU producer, experienced growth, since its vehicle production increased from 122,949 units in 2000 to 153,172 units in 2023, despite a steep 23 percent drop between 2019 and 2023 (OICA, n.d.-a).

In the United States, it is very similar story, as vehicle production decreased from 12.8 million in 2000 to 10.6 million in 2023, while it dropped even more in 2020, dipping to 8.8

million during the pandemic. Despite a recovery, 2023 figures remained below those of 2000 (OICA, n.d.-a).

China, in contrast, saw a remarkable surge in production, rising from just 2.1 million vehicles in 2000 to 30.2 million in 2023—a staggering 1,338 percent increase. This rapid growth transformed China into the world's largest producer, accounting for 32 percent of global vehicle units in 2023. Even during the pandemic, when production dipped slightly in 2020, China quickly recovered and exceeded pre-pandemic levels by 2021 (OICA, n.d.-a).

Figure 10: Shift in vehicle production from 2000 to 2023 (in million units and %)



Source: Adapted from OICA (n.d.-a).

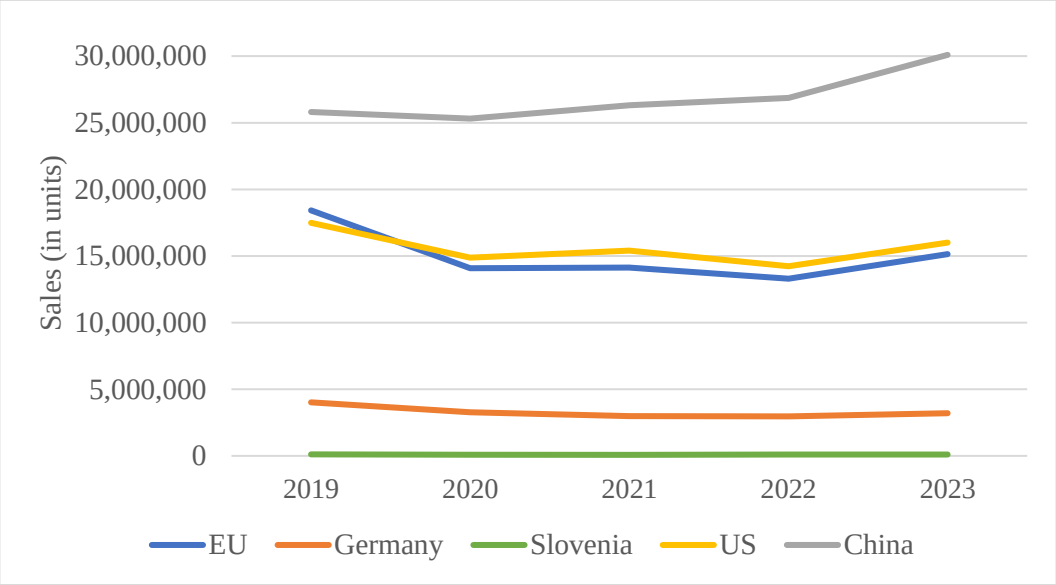
In comparison to output, global sold units shown in Table 5 reveal a modest overall growth of 0.7 percent from 2019 to 2023, driven primarily by China's remarkable performance as illustrated in Figure 11. Europe experienced a sharp decline in demand, with sales in the EU falling by 17.9 percent**,** notably impacted by Germany's substantial drop of 20.2 percent, while Slovenia showed slightly better resilience with a smaller decline of 10.6 percent. Similarly, the United States faced a moderate contraction, with sales decreasing by 8.5 percent to 16.0 million units in 2023 (OICA, n.d.-b). In comparison to production output, it is evident that the US is very import oriented, since it generated significantly higher sales than its production in 2023. The country produced just over 10 million units but sold more than 16 million. In contrast, China emerged as the dominant force in the global market, with sales growing by 16.7 percent to 30.1 million units, solidifying its role as the key driver of growth and stability worldwide (OICA, n.d.-b).

Table 5: Vehicle sales (in units) and growth (in %) by country from 2019 to 2023

	2019 (units)	2020 (units)	2021 (units)	2022 (units)	2023 (units)	Growth 2023/2019 (%)
EU	18,423,617	14,080,973	14,141,084	13,295,670	15,128,471	-17.90
Germany	4,017,059	3,266,759	2,973,319	2,963,748	3,204,298	-20.20
Slovenia	113,863	84,909	87,349	90,074	101,842	-10.60
US	17,488,154	14,881,356	15,408,565	14,230,324	16,009,268	-8.50
China	25,796,931	25,311,069	26,314,263	26,863,745	30,093,698	16.70
Total	92,065,258	79,668,562	83,638,420	82,871,094	92,724,668	0.70

Source: Adapted from OICA (n.d.-b).

Figure 11: Vehicle sales by country from 2019-2023 (in units)



Source: Adapted from OICA (n.d.-b).

2.2.4 Analysis of automotive KPIs and R&D investment

The key performance indicators (KPIs) and financial ratios are presented in Table 6. In 2023, global automotive revenues reached €3.9 trillion, lower than during the crisis years of 2020 and 2021. European motor vehicle companies generated €1.47 trillion, while US companies slipped to third place, overtaken by Japan. Chinese companies achieved €464 billion in revenues, doubling their sales over the past decade. In terms of profits, EU automotive companies led with €124 billion in 2023, maintaining the highest profits since 2013. However, Japan recorded the highest profitability, exceeding the EU by just 0.1 percentage points. Between 2013 and 2023, profitability increased in the EU, remained stable in the US, and fell in China—from 3.8 percent to 2.5 percent—likely due to slowing fossil fuel vehicle

sales and aggressive price cuts on EVs to secure market expansion (European Commission: Joint Research Centre, 2024).

A closer look about Slovenia is presented in Table 7. The revenues in 2023 reached €3.5 billion, while the profitability was three percent (Dun & Bradstreet, 2023), which is well below the European average.

In capital expenditures (capex), the EU maintained its lead between 2013 and 2023, while Chinese companies saw the highest capex growth, likely driven by the expansion of EV production. By 2023, US and Chinese automotive companies became the most capex-intensive, while capex intensity declined in the EU, Japan, and ROW (European Commission: Joint Research Centre, 2024).

Global automotive R&D investment reached €185.3 billion in 2023, accounting for 14.7 percent of total global R&D expenditure, making it the fourth-largest R&D sector. EU companies demonstrated the highest R&D intensity at 5.7 percent and contributed 45.4 percent of the sector's total R&D investment. Additionally, European automotive sector remains the top R&D investor, contributing 12 percent of the total European R&D expenditure in 2023—twice the level seen in 2013. Its companies invested over twice as much as their US counterparts (€34 billion), and more than three times as much as Chinese companies (€25 billion). However, Slovenia does not match this trend. Its R&D intensity was below two percent from 2019-2023 (Dun&Bradstreet, 2023).

In comparison, the US contributed 18.4 percent and China 13.8 percent of the sector's total R&D spending (European Commission, 2024). This contrasts sharply with the broader R&D landscape, as Europe invests less in R&D than the US or China, facing an investment shortfall of €123 billion. The EU's general R&D intensity stands at 2.24 percent, compared to 3.5 percent in the US and 2.4 percent in China (European Commission: Joint Research Centre, 2024). Despite relatively lower overall investment, Chinese companies doubled their R&D intensity over the past decade. However, the US leads in R&D per employee, increasing this figure by 68 percent since 2013 to €26,962. This is far ahead of Europe's €18,830 per employee, which ranks second globally (European Commission: Joint Research Centre, 2024).

To be more specific, Volkswagen ranks as the fifth-highest R&D spender globally, investing €21.8 billion in 2023. Mercedes-Benz also maintains a significant R&D investment, underlining the strong commitment of German automakers to innovation. Notably, Chinese company BYD nearly doubled its R&D spending from €2.4 billion in 2022 to €4.7 billion in 2023, demonstrating rapid growth and a clear focus on technological advancement (European Commission: Joint Research Centre, 2024).

Table 6: Comparison of automotive industry KPIs across the EU, US, China, Japan, and RoW for 2013 and 2023 (in € and %)

Region	Year/Growth	R&D (€ million)	Operating Profit (€ million)	Sales (€ million)	Capex (€ million)	Profitability (%)	R&D Intensity (%)	Capex Intensity (%)	R&D per Employee (€)
EU	2013	42,814	50,714	822,685	48,004	6.20	5.20	5.80	16,600
	2023	84,090	124,461	1,467,308	67,179	8.50	5.70	4.60	18,830
	Growth	96.40%	145.40%	78.40%	39.9%				
US	2013	20,578	41,126	542,099	29,463	7.60	3.80	5.40	16,011
	2023	34,082	54,208	716,467	54,558	7.60	4.70	7.60	26,962
	Growth	65.6%	31.8%	32.10%	85,2%				
China	2013	3,761	5,659	148,919	6,866	3.80	2.50	4.60	4,193
	2023	25,472	11,435	464,431	35,587	2.50	5.50	7.70	12,166
	Growth	577.20%	102.10%	211.90%	418.2%				
Japan	2013	21,304	38,268	516,257	43,571	7.40	4.10	8.40	11,902
	2023	30,980	71,840	834,756	50,817	8.60	3.70	6.10	16,786
	Growth	45.40%	87.70%	61.70%	16.60%				
ROW	2013	6,131	17,603	221,338	10,151	8.00	2.70	4.60	7,524
	2023	10,676	31,302	384,182	14,581	8.10	2.80	3.80	13,100
	Growth	74.10%	77.80%	73.60%	43.60%				

Note: Automotive industry includes Automobiles & parts; Tyres; Commercial vehicles& trucks
Profitability, R&D intensity and capex intensity are computed by dividing profit, R&D and capex by net sales, respectively. Growth refers to the growth rate between 2013 and 2023.

Source: Own work based in European Commission: Joint Research Centre (2024).

Table 7: Selected financial indicators of Slovenian automotive industry from 2020-2023

Financial indicator	2020	2021	2022	2023
Revenue (in €)	3,298,670,672	3,470,829,808	3,413,792,458	3,520,909,185
EBITDA margin (in %)	7.40	9.00	8.00	8.70
Net profit margin (in %)	2.70	4.60	2.80	3.00
ROA (in %)	4.10	7.20	4.20	4.20
ROE (in %)	10.50	17.50	10.60	9.70
No. of employees	16,963	17,088	16,823	16,825
R&D intensity	1.60	1.50	1.60	1.60

Source: Adapted from Dun & Bradstreet (2024); SiStat (2025).

2.3 Determinants of success

2.3.1 Globalization and the rise of global market leaders

Over the past 25 years, the automotive value chain has undergone significant regional shifts, driven by evolving supply and demand dynamics and the rise of global value chains. The EU automotive sector is under increasing pressure from non-EU competitors as global markets are projected to experience significant growth, while EU production remains stagnant (Stolfa et al., 2019). China has emerged as a key global supplier and consumer, although its supply primarily caters to its vast domestic market. Meanwhile, the prominence of the EU and the United States in the global automotive value chain has diminished as China's influence and regional demand have grown (Dechezleprêtre et al., 2023).

China's rise to global automotive leadership is the result of strategic, state-driven planning, investments, and a focus on scaling both production and innovation. The foundation was laid with the 1994 Automotive Industry Policy, which prioritized reducing dependence on foreign technology through joint ventures and technology transfers (Chen et al., 2024). While the EU focused on new legislation, China pursued an aggressive strategy to dominate the global automotive industry through initiatives like "Made in China 2025" and the 14th Five-Year Plan (2021–2025), which identified New Energy Vehicles (NEVs) as a strategic priority. Since 2012, China has heavily invested—between €110–160 billion by 2022—across the entire EV value chain, from raw material extraction to battery production and recycling (European Commission, 2024). Additionally, China supported the NEV by generous subsidies, which were up to 60,000 yuan (approximately €8,000) per vehicle until 2022 (Chen et al., 2024). Moreover, China secured access to critical raw materials and rapidly scaled battery production, initially prioritizing cost efficiency over performance (Chen, et al., 2024). Since the battery is currently the most valuable and technologically complex component in an EV, China also has a competitive edge due to advanced expertise in lithium battery production, because of the consumer electronics and computer industries (Altenburg et al., 2022). It encouraged foreign automakers to establish local operations through joint ventures and technology transfer agreements, while standardizing policies to ease access to technology, data, and resources. Beyond supply-side measures, China fostered a massive domestic EV market, accounting for 60 percent of global EV registrations in 2023, enabling Chinese manufacturers to achieve significantly lower costs and technological advantage through economies of scale and coordinated efforts (Chen et al, 2024). For instance, EU automotive producers struggle with 30 percent higher costs and notable technology gaps compared to China, whose OEMs lead by a generation in EV performance, software, and user experience, with development cycles nearly twice as fast (1.5–2 years vs. 3–5 years in the EU) (European Commission, 2024).

European automotive industry meanwhile faces eroding competitiveness due to missing critical elements for a successful transition. Despite investing billions in electrification, key

challenges still include insufficient charging and hydrogen refueling infrastructure, a lack of affordable green energy, limited purchase and tax incentives, and an insecure supply of essential materials such as hydrogen, batteries, and raw resources, all of which hinder the mass adoption of zero-emission vehicles (ACEA, 2024b). Additionally, European manufacturers are experiencing a decline in brand value, coupled with a rise in foreign ownership of their equity. Notably, Chinese investments in EU-based companies, such as Volvo, have increased, further shifting control and influence within the industry (European Commission, 2024).

Unlike EU, the US has responded to China's domination with large incentives like the Inflation Reduction Act and trade barriers to counter the growing presence of Chinese EVs. Tariffs on Chinese EV imports are now 100 percent and the IRA has encouraged more investment in the EV supply chain by offering tax credits to both producers and consumers (European Commission, 2024). Additionally, US strength lies in technological innovation, since US leads in cutting-edge tech such as autonomous driving and AI. It has policies and support measures that are very favorable for automotive sector such as focus on technology R&D, flexible financial support including loans, tax reliefs, and subsidies, which all promote industry advancement. Additionally, federal and state governments are investing heavily in EV charging infrastructure, expanding tax credit incentives for businesses and households that install charging stations. Their policies are increasingly geared towards reducing dependency on foreign components, enhancing domestic production capacities, and fostering innovation in clean energy technologies (Chen et al., 2024).

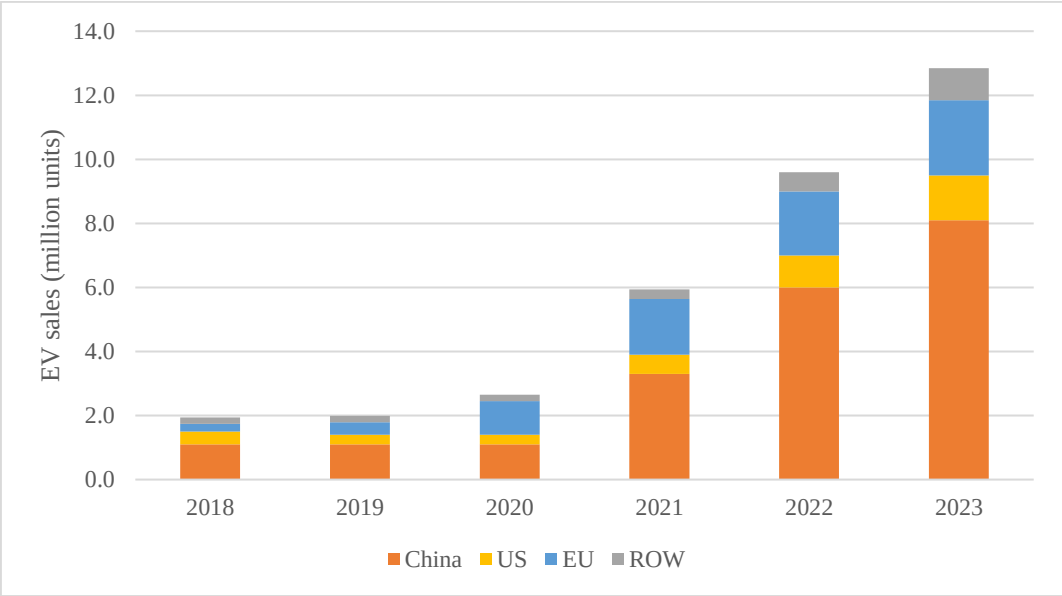
Over the past two decades, Germany and the US established globally renowned automotive brands through strategic industry policies and regulations. As China seeks to strengthen its own automotive sector, these policies now serve as a valuable blueprint for fostering industry growth and developing internationally competitive brands (Chen et al., 2024).

2.3.2 Green transition: e-vehicles and other alternative fuel sources

In the past few years, while ICE market has been declining, the EV market—including battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs)—has experienced growth (European Commission, 2024). The global fleet of EVs reached 40 million units in 2023. Globally, EVs increased their share of new passenger car sales from two percent in 2018 to 18 percent in 2023. Almost 60 percent of electric car sales were in China, 25 percent in Europe and 10 in the US (IEA, 2024a). Sold EVs are illustrated in Figure 12. Due to the concentration of sales, the global electric car stock has also become increasingly centralized. China, Europe, and the United States now account for approximately two-thirds of stock. This means that the EV transition in these key markets has significant implications for global trends. Given the observed trends, combined with ongoing policy support and the typical seasonality of EV sales, it is projected that electric vehicle sales could reach 17 million units in 2024. This suggests strong growth in a maturing market, with 2024 global sales expected

to exceed 2023 levels by over 20 percent, and EVs accounting for more than 20 percent of total car sales (IEA, 2024a).

Figure 12: Sales of electric vehicles in China, the US, EU and RoW from 2018-2023 (in million units)



Source: Adapted from IEA (2024a); European Alternative Fuels Observatory (n.d.).

The primary driver accelerating the European automotive industry's shift toward electromobility are sustainability goals and targets (Nettekoven & Mualla, 2023). The EU's climate policy has set ambitious green house gas (GHG) reduction targets for road transport (European Commission, 2024). It has established 2035 as the effective deadline for ending sales of cars and vans with ICEs under the EU's CO_2 fleet standards (Regulation - 2019/631 - EN - EUR-LEX, n.d.) and set significant cuts also for trucks and buses (65 percent by 2035 and 90 percent by 2040). Beginning in 2027, road transport will be included also in the EU Emissions Trading System (ETS 2), which will rise ICE mobility costs and drive the transition to low-emission vehicles, particularly BEVs (European Commission, 2024). European automotive manufacturers are facing challenges due to stringent regulations aimed at promoting green transitions (Tamma & Hancock, 2024). In fact, the European automotive industry is one of the most heavily regulated, being implicated in more than 150 EU regulations and 30 directives (ACEA, 2023).

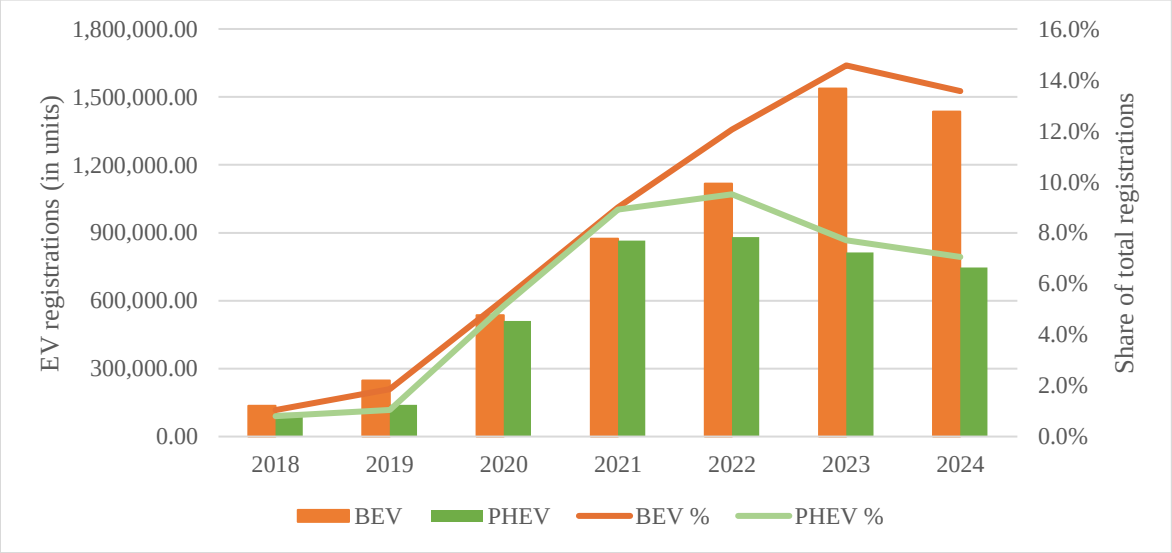
BEVs are therefore seen as the key decarbonization technology and the future of road transport for achieving net-zero emissions, particularly from a tank-to-wheel perspective (European Commission, 2024). However, EV carbon footprint is largely influenced by battery production and material extraction (Xiong et al., 2020; Richert & Dudek, 2023). EV battery production can emit 50 percent more GHG than ICE vehicles, primarily due to fossil-fuel electricity and energy-intensive manufacturing (Kim et al., 2021). Overall, EV production emits 14.6–14.7 tons of CO_2, 59–60 percent more than ICE vehicles, with battery

manufacturing as the largest contributor (Qiao et al., 2017; Kim et al., 2016). Battery disposal adds another 1,900 kg of CO_2. Despite these impacts, EVs emit fewer GHGs over their lifecycle, if charged with clean energy. However, challenges like driving range, charging infrastructure, and affordability persist (Richert & Dudek, 2023; Pan et al., 2023).

In EU, biggest shift to EVs started happening after 2019, when EVs accounted for 2.91 percent of new passenger car registrations, more specifically, almost 400 thousand cars, as presented in Figure 13. Until 2023, EV new registrations were growing and reached 22.3 percent, which was 2.3 million vehicles, with BEVs comprising 14.6 percent and PHEVs 7.7 percent. However, in 2024, BEV market share declined, reaching total market share of 13.6 percent, while PHEV fell to 7.1 percent share (European Alternative Fuels Observatory, n.d.). Significant decrease was seen in Germany and France (ACEA, 2025).

In Slovenia specifically, there were 3,148 new BEV registrations in 2024, marking a 27.3 percent decline from 2023, when 4,330 cars were registered. PHEV registrations remained relatively stable, with only six more vehicles registered in 2024 compared to 1,156 in 2023 (ACEA, 2025). However, when compared to 2019, the combined total registrations of EVs for both categories were 651 vehicles (ACEA, 2020).

Figure 13: European electric vehicle registrations (in units) and their share of total vehicle registrations (in %) by category from 2018-2024



Source: Adapted from European Alternative Fuels Observatory (n.d.)

Some say that the demand slowdown and current stagnation of EVs in Europe has been anticipated for some time (T&E, 2024). The European automotive sector exemplifies the EU's failure to align climate policy with industrial strategy, highlighting a lack of cohesive planning (European Commission, 2024). European weak industrial policies and uncertainty over the 2035 zero-emission car target detered investment and undermined Europe's competitiveness. Between 2021 and 2023, Europe attracted only 26 percent of global EV

investment, while North America, a smaller car producer, secured 37 percent. The EU's stop-and-go car CO_2 targets, set in five-year intervals, have encouraged carmakers to delay scaling up EV sales until mandated by regulations, instead focusing on maximizing profits from ICE vehicles and high-end EV models in the interim. Between 2021 and early 2024, the average EV price rose from under €30,000 to over €40,000, with large models dominating sales (T&E, 2024). The high cost of EVs is a major barrier to fleet modernization. In 2023, the cheapest new EV in Europe was 92 percent more expensive than the lowest-priced ICE car, mainly due to battery and powertrain costs. In smaller vehicles, batteries make up 40 percent of material expenses. Surveys show cost is the top obstacle to EV adoption, with many consumers open to BEVs if models were priced around €20,000. Other issues include low resale values and high insurance premiums driven by expensive repairs and battery replacements (European Commission, 2024). However, from 2025, automakers plan to boost EV sales with affordable, mass-market models to meet stricter EU CO_2 targets, including launching ten budget-friendly Made-in-Europe EVs (T&E, 2024).

Additionally, many EU member states provide incentives for EV adoption, but the conditions differ significantly, with some offering no purchase subsidies at all, while only five countries offer support for charging infrastructure (ACEA, 2024a). In fact, adequate charging and refueling infrastructure is a critical enabler for developing a robust domestic market for EVs. While the installation of charging stations has grown and the market has become more competitive, charging capacity still varies across EU Member States, closely linked to EV uptake (European Commission, 2024). Additionally, only half of EU residents and slightly fewer in the US have access to off-street parking suitable for home charger installation. To support electrification, an estimated 6.8 million public chargers will be required by 2030. However, private passenger vehicles are not the sole focus. As public transport, ride-sharing, and fleet operations transition to electric, a diverse and scalable charging infrastructure will be essential to meet their needs (WEF, 2024).

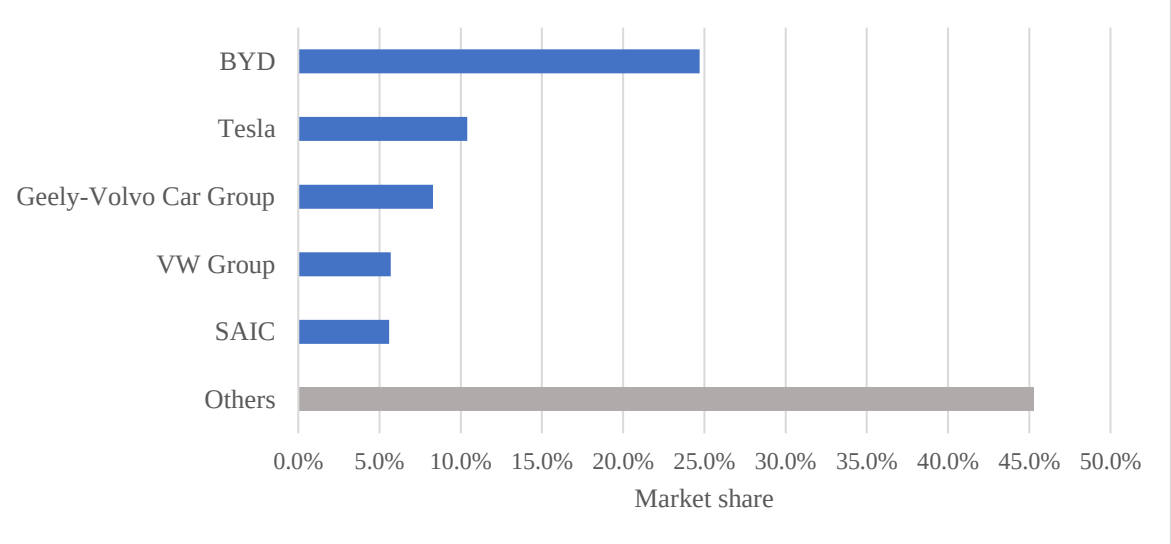
China, on the other hand, has shown significant growth in EV registrations. It registered 8.1 million new electric cars in 2023, a 35 percent increase compared to 2022. Because of EV sales growth, its car market grew by five percent despite an eight percent decline in sales of ICE vehicles. This marked the first year China’s NEV industry operated without national subsidies, although tax exemptions and province-led support remained to sustain the market. Price competition and industry consolidation intensified as the market matured. EVs exports grew by 80 percent from 2022, primarily targeting Europe and Asia Pacific markets such as Thailand and Australia (IEA, 2024a).

In fact, electric cars in China have become more affordable than ICE cars, with the sales-weighted average price of EVs already lower than ICE vehicles, even in the small car and SUV segments. China has nearly 50 models priced under CNY 100,000 ($15,000), comparable to popular small ICE cars. Additionally, by 2022, electric SUVs were on par with conventional ones after accounting for the EV exemption from the 10 percent vehicle purchase tax. Since 2018, EV prices have significantly dropped, and in 2022, around 55

percent of electric cars sold were cheaper than their ICE counterparts, a figure that rose to approximately 65 percent in 2023 (IEA, 2024a). China's ability to produce affordable EVs has flattened prices globally, strengthening its position in international markets (Letzing & Sung, 2024).

Chinese more competitive pricing is evident in their growing market share in the EV industry. For instance, BYD sold over four million EVs in 2024, capturing approximately a quarter of the market, as illustrated in Figure 14. In comparison, Tesla delivered nearly 1.8 million EVs, securing around 10 percent market share. Meanwhile, Volkswagen, the leading European automaker, held a more modest 5.7 percent share of the EV market (Pontes, 2024).

Figure 14: Global plug-in EV market share in 2024, by manufacturer



Source: Adapted from Pontes (2024).

In comparison to China and EU, the United States saw 1.4 million new electric car registrations in 2023, a growth of over 40 percent from 2022, though growth was slower than in prior years. Demand remained robust, bolstered by the Clean Vehicle Tax Credit under the IRA and price reductions on popular EV models like the Tesla Model Y, which saw sales increase by 50 percent after becoming eligible for the full $7,500 tax credit. While stricter domestic content requirements for EV and battery manufacturing caused concerns, leasing models allowed some vehicles to qualify for less restrictive commercial tax credits, sustaining sales (IEA, 2024a).

Additionally, between 2018 and 2022, the average price of EVs in the US fell, driven by Tesla's price cuts, with electric SUVs seeing sharper declines than battery costs. By 2023-2024, Tesla's Model 3 ($39,000–$42,000) matched the average ICE car price, and a Model Y under $50,000 was launched. For 2024, 25 new EV models are expected, but only five will be under $50,000, and none below $30,000. Despite tax credits, 75 percent of EVs will exceed $50,000, limiting competition with mass-market ICE cars (IEA, 2024a).

Hydrogen is an emerging solution for decarbonizing transport and industry. It can be produced from fossil fuels, coal, or clean electricity and used for power generation without CO_2 emissions (Boussidan, 2023). While mainly used in petrochemicals, food processing, and fertilizers, it also powers fuel cell electric vehicles (FCEV), which emit only water and offer longer ranges and faster refueling than battery EVs (Gençer, 2023; Pan et al., 2023). Regulatory frameworks like the Paris Agreement, European Green Deal, the European Hydrogen Bank as well as IRA in the US are helping make hydrogen a reality (Kolodziejczyk, 2024).

By June 2024, the global stock of fuel-cell electric vehicles reached approximately 93,000. Korea leads in fuel cell car deployment, holding over half of the global total, followed by the US with a quarter and Japan with over 10 percent (IEA, 2024b). In 2023, hydrogen use in road transport rose by 55 percent, driven largely by heavy-duty vehicles, which accounted for nearly 85 percent of this growth. However, trucks, buses, and vans together made up only about 30 percent of the FCEV stock by mid-2024. In China, where FCEV deployment focuses on high-mileage heavy-duty vehicles, hydrogen consumption for transport grew nearly twice as fast as in the US and more than three times as fast as in Europe. Fuel cell vans in China outnumber cars by more than four to one, representing over 90 percent of the global total, further highlighting the emphasis on commercial fleets (IEA, 2024b).

Meanwhile in EU, there have been only 23 hydrogen FCEVs in 2013, while in 2024, they increased to 4711 vehicles. However, the number of newly registrations in 2023 and 2024 was quite lower than in 2021, since there have been only 916 cars registered compared to 1279 in 2021 (European Alternative Fuels Observatory, n.d.).

FCEVs face challenges, including issues with hydrogen production, storage, refueling infrastructure and higher costs compared to conventional vehicles (Pan et al., 2023). A key concern is hydrogen's carbon intensity and classification (Kolodziejczyk, 2024). Hydrogen requires compression or liquefaction for transport and storage, necessitating costly specialized infrastructure (Fan et al., 2021). Its environmental impact depends on the production method (Gençer, 2023), with most hydrogen (over 80 percent) coming from fossil fuels, and less than one percent from low-emission sources in 2022. Electrolytic hydrogen, though currently only 0.1 percent of production but dominates in announced future projects, is expected to grow as costs decline (IEA, 2024b). While renewable or nuclear hydrogen has lower emissions, some sources, like biomass, can be as polluting (Kolodziejczyk, 2024). Despite high energy content per weight, hydrogen’s low volume density complicates storage and distribution (Fan et al., 2021).

2.3.3 Sourcing and supply chain challenges

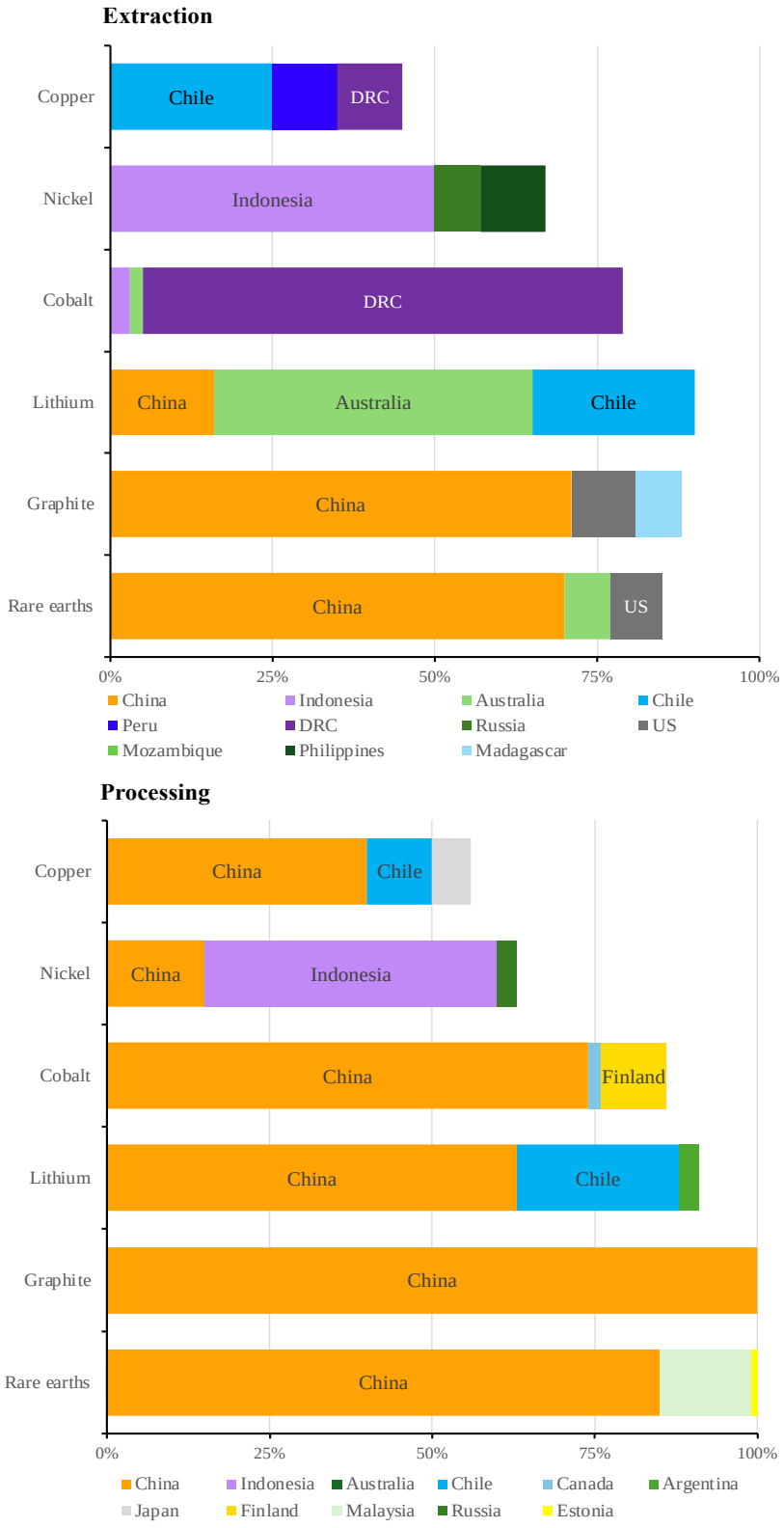
Since electric mobility is reshaping the automotive value chain, there is an increased demand for batteries and battery materials (Dechezleprêtre et al., 2023; Altenburg et al., 2022). In 2023, global battery demand reached over 750 GWh, a 40 percent increase from 2022,

largely fueled by EV sales, with electric cars accounting for 95 percent of this growth (IEA, 2024a). The EU accounts for just 6.5 percent of the global lithium-ion battery market, but its battery manufacturing output reached approximately 65 GWh in 2023, a 20 percent increase from the previous year. By comparison, the US produced 80 GWh with similar growth, while China led with 670 GWh and a 50 percent growth rate. Around 50 – 70 percent of battery cells in EU products still come from China (European Commission, 2024).

Global electric battery exports totaled €14.2 billion in 2000, with Japan emerging as the largest exporter, generating €4.6 billion of exports, which is 32.4 percent of total, followed by the United States (12 percent) and China (10.5 percent). On the import side, the United States led, representing 16.1 percent of global imports, followed by Mexico and Hong Kong with a much lower share. By 2023, the landscape had shifted. Exports surged to €147.2 billion, which is 1114 percent growth. Moreover, the exporters dynamic also changed significantly. China not only became the largest exporter but secured more than half of market share, with €74 billion of electric batteries exported. Japan drastically fell in exports, since its market share was only 2.88 percent in 2023. No other country even came close to China, since the second biggest exporter was Poland with 8 percent share, exporting €11.8 billion of electric batteries. On the import side, the Germany became the biggest importer, importing €26.8 billion, United States followed with slightly lower value of 24.7 billion. More specifically for Germany, in 2010, it imported almost a quarter of electric batteries from China (€260.1 million). By 2023, nearly half (€12.3 billion) came from China—representing an incredible 3,755 percent growth (OEC, 2025a).

Notably, battery demand is increasing the demand for critical raw materials (CRMs) (European Commission, 2024). Batteries represented 85 percent of total lithium consumption, 70 percent of cobalt, and over 10 percent of nickel in 2023 (IEA, 2024b). Europe's automotive industry is heavily reliant on CRMs since the mining and processing of these materials are very concentrated, around 40 percent of imports coming from a small number of suppliers, many in non-strategic partner countries. Figure 15 exhibits that the main producing countries are China, Australia, Chile, Indonesia and Democratic Republic of Congo. Between 2017 and 2022, lithium demand tripled and cobalt rose by 70 percent, yet diversification efforts have made little progress, leaving Europe vulnerable to supply disruptions and geopolitical pressures (European Commission, 2024; Altenburg et al., 2022).

Figure 15: Share of top producing countries in total extraction and processing of critical resources and minerals (in %) in 2022



Source: Adapted from European Commission (2024).

China is a dominant player in extraction and processing of materials as well as production of batteries. In fact, 76 percent of global capacity for manufacturing batteries is in China. This capacity is expected to at least cover the level of global demand or even reach double the level (European Commission, 2024). China is also processing 35-70 percent of key CRMs such as graphite, copper, lithium, and cobalt, and has shown a willingness to leverage its market power through export restrictions, which increased ninefold between 2009 and 2020 (European Commission, 2024). Additionally, it is the largest producer of natural graphite and has a 79 percent market share. Although graphite mines exist in various parts of the world, all graphite is currently shipped to China for processing into anode materials used in batteries (Ritoe et al., 2022). It is important to highlight that the supply of flake graphite for electric vehicle batteries is entirely dependent on Chinese production, which creates a monopoly over supplies (Richert & Dudek, 2023).

This concentrations create major challenges for the EU's automotive sector, including geopolitical risks, potential coercion, and price volatility, which weaken policy objectives, erode business confidence, and hinder investment decisions (European Commission, 2024).

2.3.4 Technology advancements

The automotive industry is positioned to use AI innovation to transform the entire manufacturing process by leveraging its ability to process data, improve performance, reduce material use, streamline supply chains, and increase productivity. Moreover, digital technologies are driving transformative changes in advanced driver-assistance systems, connected vehicles and autonomous driving capabilities (European Commission, 2024).

The global automotive industry has long been a pioneer in adopting automation technologies, from assembly lines to industrial robots (European Commission, 2024). In fact, the automotive industry has the largest number of robots in factories worldwide, with approximately one million units in operation. This represents about one-third of all robots installed across various industries. In 2023, automotive robots accounted for 135,461 new installations globally, outpacing all other industries that year (IFR, n.d.). Robots are instrumental in supporting the industry's transition from ICE vehicles to EVs, as robotic automation enables car manufacturers to navigate the significant shifts required in long-established manufacturing processes and technologies (IFR, 2023).

Robot density, a key measure of automation, shows that in 2021, the Republic of Korea led with 2,867 industrial robots per 10,000 employees in automotive industry. Germany ranked second with 1,500 robots, followed closely by the United States with 1,457, and Japan with 1,422 robots per 10,000 workers. China only has a robot density of 772 robots, but is rapidly catching up. In just one year, its robot installations in automotive sector nearly doubled, reaching 61,598 units in 2021, which represented 52 percent of the global total (119,405 robot units) installed worldwide (IFR, 2023).

Additionally, as the production of EVs is growing, Europe's battery R&D investment has grown 18 percent annually, boosting patent applications and advancing sodium-ion and solid-state technologies to reduce costs and dependencies. While major firms collaborate on solid-state batteries for improved safety and lifespan, many projects depend on supportive policies. Nearly half of announced investments come from non-EU firms, limiting local expertise development (European Commission, 2024). Similarly, US tech firms, in partnership with federal labs, use AI to cut lithium in batteries by 70 percent, reducing reliance on critical materials. The IRA is expected to provide $40–$250 billion to bridge the US-China cost gap in clean tech manufacturing (European Commission, 2024).

Moreover, an increasing portion of vehicle value is attributed to software. Projections suggest that by 2030, electronics and software could make up to 50 percent of a car's value (European Commission, 2024). As a result, the industry is gradually shifting from a mechanical, transportation-focused approach to a software-driven, technology-centric one (Hojdik, 2021). Many OEMs have already initiated pilot projects or proofs-of-concept for AI applications (European Commission, 2024). However, while Europe has long been a leader in the automotive sector, it risks falling behind in autonomous driving, with US manufacturers currently responsible for nearly 70 percent of all kilometers driven by Level 4 fully autonomous vehicles (Smit et al., 2022). Autonomous driving (AD) technology has advanced significantly in the past years, with the passenger car segment projected to generate $300–$400 billion in revenue from AD features by 2035 (Deichmann et. al., 2023). The EU is heavily investing in automation through Horizon Europe, allocating €500 million to a public-private Cooperative, connected, and automated mobility (CCAM) partnership, matched by private contributions. Since 2021, €159 million has funded 19 research and innovation projects (Directorate-General for Research and Innovation, 2024). However, Europe's still limited scale in transversal technologies risks undermining its competitiveness (Smit et al., 2022). While Europe prioritizes safety, digitalization and requires extensive testing and approval processes, China benefits from government-driven standardization, which accellerates implementation. On the other hand the US has problems with regulations varying by state, which also creates inconsistencies (Deichmann et. al., 2023).

Additionally, over 90 percent of vehicles sold by 2030 are expected to be connected, up from 50 percent today, showing rapid adoption and integration of connected technology in cars. BEV-focused manufacturers and Chinese OEMs have long recognized the importance of connectivity and are significantly enhancing their offerings. Features such as seamless AI-powered voice assistants, subscription models for autonomous driving, advanced security features, and entertainment options like gaming are becoming popular. Western OEMs lag behind Chinese manufacturers. For instance, many features offered as standard by Chinese OEMs are still available only as optional extras at Western OEMs, (Baule et al., 2024).

At present, only 11 percent of EU companies use AI, far from the 75 percent target by 2030. Meanwhile, 73 percent of foundational AI models since 2017 have come from the US and

15 percent from China (European Commission, 2024). Europe therefore risks becoming entirely dependent on AI models designed and developed abroad, not only for general-purpose AI but also for industry-specific applications used in automotive sector (European Commission, 2024).

2.3.5 Changing consumer preferences

Despite increasing interest in EVs, widespread adoption in Europe still faces major challenges. High purchase prices are a key concern for 37 percent of respondents in a McKinsey study, along with limited battery range (36 percent) and concerns about battery lifespan (35 percent). Additionally, rising electricity costs and inadequate public charging infrastructure further diminish the practicality of EVs, especially for mainstream buyers, such as older consumers and those on tighter budgets, who are slower to make the switch. While younger, environmentally conscious urban consumers and premium-brand buyers have been early adopters, cost and convenience continue to outweigh sustainability as the key deciding factors for many potential buyers (Venus et al., 2024).

Beyond the initial adoption hurdles, some current EV owners are reconsidering their choices and even looking to return to ICE vehicles. The main driver of this shift is cost, with 41 pecent of EV owners citing high ownership expenses, reduced subsidies, and lower-than-expected resale values as reasons to switch back. Unless manufacturers can address these financial, infrastructure, and performance concerns, the green transition in mobility may continue to stall (Venus et al., 2024).

There is growing demand for connected vehicle features, with 40-60 percent of global survey respondents interested, especially in China (65 percent) and the US (55 percent), while Germany is more reluctant (45 percent). BEV owners are even more likely to purchase these features, ranging from 49-63 percent. But the consumer preferences in this area vary widely across regions. Chinese consumers lead the world in their willingness to pay for connectivity services, with 65 percent expressing a strong desire to adopt connected vehicle features. This highlights a significant appetite for new technologies in the region. In comparison, 55 percent of US consumers are also willing to pay for these services, though slightly less than their Chinese counterparts. On the other hand, German consumers are the most reluctant, with only 45 percent willing to invest in connectivity features. These regional differences reveal varying levels of openness to adopting advanced vehicle technologies. While China shows a higher degree of enthusiasm for connectivity, US and German consumers are more cautious, with Germans being particularly conservative in their approach to investing in these features (Baule et al., 2024).

3 METHODOLOGY

The thesis investigates the following research questions:

- Is Europe losing its competitive edge and what are the reasons for it?
- Are the European and Slovenian automotive industries moving in the right direction?
- How do green transition initiatives impact the success and competitiveness of the European and Slovenian automotive industry?
- Are Europe and Slovenia well-positioned to adapt to emerging trends in the automotive industry?

In-depth interview is a qualitative research method aimed at gathering detailed insights into a respondent's views, experiences, interpretations, and reactions to a particular phenomenon. Unlike quantitative interviews, which offer predetermined response options, in-depth interviews are open-ended, allowing participants to share their thoughts in their own words. The structure of the interviews used was semi-structured, with some flexible topics explored but room for flexibility. This flexibility enabled to uncover aspects that may not be captured through more structured approaches (Jennings, 2005).

Table 8: List of interviewees

Company	Position in value chain	Size	Interviewees	Code
Company 1	Tier 1	Medium	CTO	Interview1
Company 2	Tier 2	Big	CEO	Interview2-1
			Sales	Interview2-2
Company 3	Supportive services	Big	Head of E-infrastructure and charging service for EVs	Interview3-1
			Product manager	Interview3-2
Company 4	OEM	Big	Member of management board	Interview4-1
			Supply chain and purchasing officer	Interview4-2
Company 5	Tier 2	Big	CEO	Interview5
Company 6	Tier 2	Big	CEO	Interview6
Company 7	Tier 3	Small	CEO	Interview7
Company 8	Tier 3	Small	CEO	Interview8
Company 9	Tier 1	Big	Vice president Mechatronics	Interview9

Source: Own work.

In-depth interviews were conducted as part of the PKP project within the IMB master's program between August 26 and September 6, 2024. The gathered insights provided the foundation for analyzing the competitiveness of the automotive industry. Interviews were

done with industry professionals, including OEMs and Tier 1-3 suppliers, to gather firsthand information on the competitiveness of the Slovenian and European automotive sectors, perceptions of transitioning to e-mobility, the impact of regulations, supply chain challenges and their implications, as well as technological advancements (Končan, et.al, 2024). The sample included companies of varying sizes, ranging from small suppliers to large, established players, while interviewees were primarily top-level executives, such as CEOs, CTOs, and members of management boards. The firms were selected through convenience sampling and spanned a range of products and services, including plastics, springs, electric motors, technological solutions development, and others, reflecting the wide variety of sectors within the automotive value chain.

4 ANALYSIS AND RESULTS

4.1 Competitiveness of Slovenian and European automotive industry

The main questions addressed Slovenia's position in the automotive market, the challenges it faces, its competitive advantages, and its comparison to other major market players.

The automotive sector in Slovenia operates within a highly competitive global environment. Despite having *"similar infrastructure and economic conditions to other European players like Germany and other producers, Slovenia is highly dependent on them"* (Interview2-1).

As one industry professional observed, *"The car industry here is strong, but the market is small, competition is fierce, and practically everything is exported"* (Interview4-2). Slovenia's automotive sector also does not have large dominant companies, making it different from major European automotive hubs like Germany, France, or even neighboring Austria. Instead of having a few key industry leaders, Slovenia consists mostly of many small and mid-sized suppliers competing in the same space (Interview7). *"The country is so small that we all know each other and we are all capable of the same thing"* (Interview7).

Slovenia has a skilled workforce, yet struggles with innovation and product development. *"We are a very hard-working workforce, but what we lack is the ability to build on that. We are not innovative enough in our product development"* (Interview4-1). However, most company representatives interviewed recognize that Slovenia benefits from a combination of expertise and quality. *"Quality is definitely one of our strengths"* (Interview5). Slovenia's strenght is also recognised by other countries: *"Germans admit to us that we are smarter, faster, and more responsive" (*Interview8-1). The advantage is reinforced by Slovenia's robust educational system, which provides a solid foundation for specialized industries. *"Slovenia has strong technical education, which supports high-value manufacturing and R&D"* (Interview9). Due to technical expertise, *"Slovenia should further emphasize high-value production, as this is an area where it can make a significant contribution"* (Interview5).

However, *"Slovenia is not investing enough in skilled workers"* (Interview6), which is making it harder to remain competitive. On the other hand, *"labour costs in Slovenia are increasing faster than in other regions, with a sharp rise observed in 2023"* (Interview4-1), which intensifies the pressures. As labour costs rise, businesses are looking for ways to offset them and maintain their competitiveness. *"Automation could be a solution to maintain cost efficiency, similar to what Austria and other highly developed European economies are doing"* (Interview4-1).

Additionally, as many other European countries, *"Slovenia struggles with unpredictable energy prices"* (Interview6). As these costs continue to climb, concerns grow about Slovenia's long-term competitiveness in manufacturing. If this trend persists, companies may start shifting production elsewhere.

Slovenian automotive companies also face challenges due to their smaller size, which limits their production capabilities and makes competing with larger players more difficult. *"The supplier must be capable of developing many different products, which Slovenian suppliers struggle to do. Even though they produce excellent products, they lack the capacity. This is where the Germans have an advantage"* (Interview4-2). Additionally, while it's crucial to produce large quantities, diversifying the customer base is equally important, though it remains challenging. *"It's essential that a supplier isn't dependent on a single customer, which becomes problematic when sourcing over 100 different components for large batches" (Interview4-2).* Slovenian companies therefore face difficulties in achieving high level of production for individual client while maintaining a broad customer base to avoid being overly reliant on a single customer. Despite these challenges, Slovenia plays a crucial role in certain specialized sectors: *"Slovenia is the big electric motor hub, so all electric motors are being developed in Slovenia"* (Interview9). Additionally, Slovenian companies provide high-value components for tier-1 suppliers (Interview6).

However, there are also some systemic challenges, including high corporate taxes, limited government support, and a lack of cohesive industrial policies. One industy professional highlighted this gap: *"We have the expertise and geographical advantage, but with minimal government support and higher profit taxes, there's no clear policy guidance"* (Interview7). Because the Slovenian government does not actively support industrial policies, *"companies are left to figure things out on their own, unlike in other countries"* (Interview7). While Austria and Germany invest in strategic industrial policies to support their automotive sectors, Slovenian companies lack similar institutional backing and receive minimal state aid compared to other countries (Interview7). *"Slovenia needs a clearer industrial policy that focuses on making manufacturing more competitive like securing resources such as aluminum and lithium*" (Interview6).

At the same time, external pressures are rising, with intensifying competition from Eastern markets, particularly China, making it increasingly difficult for European companies to keep up due to *"intense price pressures"* (Interview4-1). Slovenian businesses, for instance,

acknowledge the growing pressure. As one expert pointed out, *"We'll just have to make our products cheaper while improving them at the same time"* (Interview8-2). Chinese manufacturers, supported by substantial subsidies, have made notable strides in quality in the last decade. *"Their quality is really good, especially companies like BYD. They're likely to dominate the market"* (Interview2-2). China possesses knowledge and has invested in automation and robotics, which enhance production efficiency and quality (Interview5). However, Chinese vehicles often come with different safety features, making them cheaper to produce. "*Chinese vehicles can be more affordable because of these safety differences, but for the European market, they would need to be slightly more expensive"* (Interview4-2). European companies therefore face the challenge of adapting to this environment and stay competitive while adhering to the region's strict safety and quality standards.

To counter these challenges, Slovenian companies are exploring different strategies. One approach involves diversifying their markets and focusing on higher-value products. *"We need to diversify—decide whether to compete with China or enter the US or Western EU markets, and also move further upstream"* (Interview1). Others are leveraging partnerships with Chinese firms to learn from their fast-paced approach. *"We are working with our Chinese partners to understand what they do differently so we can speed up our processes"* (Interview4-2). The core issue lies in the way European companies approach development. European firms tend to be slow and methodical, focusing on every last detail. *"We Europeans try to develop everything to perfection, but we're slow, and trends change in the meantime. It would be beneficial to develop certain things in China, where decision-making is quicker. They don't over-discuss; once they agree, they act. Their work ethic and approach are simply different"* (Interview4-2). This ability to execute rapidly gives China a significant competitive edge, particularly in industries where speed and cost efficiency are crucial. *"China is running at a completely different speed. Their expectations in terms of speed, innovation, and cost are completely different from Europe"* (Interview9).

4.2 Green transition: electric vehicles and alternatives to ICEs

The main questions addressed the transition to electric mobility, the feasibility of electrification, the main challenges involved, and the state of the competitive landscape. Additionally, the discussion covered hydrogen, exploring both its advantages and the challenges associated with it.

Europe is focusing heavily on sustainable mobility, positioning it as a cornerstone of its future strategies. Electrification is viewed as a key solution for achieving greener transportation, driving significant innovation and policy efforts. However, industry experts emphasize that this transition is far from straightforward, with differing opinions fueling ongoing debates within the sector.

There are some important questions about energy sources and battery production that underscore the complexity of achieving a greener future. *"Key issues remain unanswered: where does the energy originate, and how do we produce the batteries?"* (Interview2-1). One industry professional commented *"Electrification is an ideal concept in theory, but several challenges remain. One issue is dependence on raw materials and the dominance of supplier countries. Recycling batteries and their environmental impact is also a major concern"* (Interview5). The latter is problematic, since no one wants to do it. *"Currently, recycling batteries isn't economically viable. There's no profit to be made in it, but incentives could potentially drive change in this area"* (Interview2-1). Without addressing these issues, achieving truly sustainable mobility remains a challenge. However, even if questions about sourcing sufficient energy and improving production and recycling processes were resolved, the issue would still not be entirely addressed. Another problem arises from managing surplus energy: *"A significant challenge is our inability to store energy effectively. When demand spikes, everyone needs energy at the same time, but we can't save the surplus during low-demand periods"* (Interview6).

From a financial perspective, EVs also remain costly to produce and yield lower profit margins for manufacturers. *"We are somewhat disillusioned—EVs aren't ready for mass adoption due to their high production costs, which cause OEMs to lose money. The products themselves still need improvement"* (Interview1).

This issue becomes even more pronounced when compared to the influx of competitively priced alternatives entering Europe from the Far East. *"The Chinese market is ahead of us. We don't even have a competitive car in the EV market compared to China"* (Interview6). In recent years, Chinese automakers have been aggressively expanding into Europe, offering competitively priced EVs with improved quality. This shift is already becoming visibly noticeable in certain regions. *"Chinese cars are entering Europe aggressively. I saw hundreds of them in Sicily, and people are also starting to notice"* (Interview7). "*It is a bit shocking to see that people decided to buy BYDs over BMWs, something you wouldn't expect a few years ago in Germany"* (Interview1).

China has a cost and regulatory advantage**,** making it harder for EU manufacturers to compete. *"It is difficult to expect it will stop now, because I know that in China there are about 30 manufacturers of electric cars"* (Interview5).

While EV adoption is gradually increasing among European consumers, *"*the *primary factor influencing mass adoption is car price, and EVs are significantly more expensive*" (Interview3-2). With Western automakers struggling to lower costs, the affordability gap between their EVs and Chinese imports continues to grow, raising concerns about their ability to stay competitive. "*If electric mobility is coming, the average user won't pay €50,000–€70,000 but will look for cars in the €25,000–€30,000 range. Will Western automakers provide them, or will buyers turn to SAIC and BYD?"* (Interview9).

Additionally, while early adopters embraced EVs, the broader public remains cautious. Despite EU targets pushing for electrification, consumer demand does not fully align with the EU's vision. *"Early forecasts from Slovenian ministry and consultants significantly overestimated EV adoption rates"* (Interview3-2), leading to misaligned expectations. This gap between projections and reality is evident in current registration numbers, which remain far below initial targets. *"We now have around 12,000 electric vehicles registered in Slovenia, which is one percent of the whole personal vehicles registered in Slovenia"* (Interview3-1).

Many drivers still prefer durable, high-performance cars over EVs. *"The EU pushes electric cars, but the reality is different—people still want powerful combustion cars that last long"* (Interview7). "*It seems people aren't keen on dealing with the challenges of EV ownership, like charging. The majority of new consumers don't yet see the benefits of switching. If it's not convenient, people won't switch"* (Interview2-1). What is more problematic is the disconnect between product design and consumer needs in the European EV market. *"Electric vehicles in the EU aren't built with consumers in mind but rather to meet regulatory requirements. These are premium products aimed at the upper class, whereas Chinese manufacturers focus on affordable options for the masses"* (Interview6).

Despite China's rapid technological advancements in EVs, there are still some qualitative or strategic differences between Chinese and European electric vehicles. *"Europe and Slovenia, in particular, should focus on high-value, specialized solutions instead of directly competing with China on large-scale EV production. Competitive advantages will come from innovation and patents, rather than mass production"* (Interview5). However, *"Slovenia is losing in terms of fast electrification. There are not enough companies and parts to add or develop"* (Interview5).

Diving deeper into European EV purchases, experts noted that EV adoption is run by incentives. *"Companies are purchasing EVs primarily because of subsidies, tax breaks, and other financial incentives"* (Interview7). Similarly, producers are motivated by the benefits associated with green initiatives as well. However, for the industry to truly embrace green mobility, regulatory frameworks are essential. As one expert explained *"Green mobility will gain traction once it's tied to bonus schemes for OEMs; otherwise, cost will dominate decisions. Regulation remains the only real driver"* (Interview2-1). Moreover, adoption of EVs in Germany for instance is higher, also because Germany introduced *"low-emission zones and bans on certain internal combustion vehicles in city centers, which are helping EV adoption*" (Interview3-1).

While many factors contribute to the success and viability of electrification, another critical one is the availability of robust infrastructure. In regions with well-established charging networks, EVs perform effectively. However, challenges arise in areas with longer travel distances or significant temperature fluctuations. *"There's more than one viable solution. With proper infrastructure, electric vehicles work well, but for longer distances or extreme*

temperature changes, the situation becomes more complex" (Interview5). Some experts are more skeptical about the infrastructure's ability to support such a transition, arguing that it may be unrealistic given current capabilities and future demands. *"We cannot expect a billion cars to be connected to the electric infrastructure. Infrastructure for EVs is not ready and the network would not withstand it. We would need at least five to ten more years of heavy investment to make it possible"* (Interview7). Europe still needs to enhance its infrastructure, but Slovenia requires even greater effort, "*Germany and Austria are much ahead of Slovenia" (Interview8-1).*

However, some have a different opinion. *"Slovenia has good charging infrastructure relative to EV adoption, but overall adoption remains low. We are one of the top countries in Europe for EVs per charging station—on average, one public charging station serves six cars"* (Interview3-2). Furthermore, the growth of the renewable energy sector—and with it, the transition to electric cars—could accelerate if the systems were more business-friendly. *"Our company is investing millions in big wind power plants and solar farms, but Slovenian procedures for approval are complicated. We even deployed two big wind power plants in Croatia because of that"* (Interview3-2). In contrast, China has rapidly scaled up its renewable energy production, surpassing both Europe and the US. China produces significantly more renewable energy than Europe and the US combined, suggesting Europe is lagging behind in energy transition efforts. *"Out of all renewable energy produced in the world, Europe and the US produce only one ninth of what China does"* (Interview6).

Green transition is complex, not only in infrastructure and energy production but also in broader mobility strategies. While electrification is a key pillar of sustainability, experts emphasize that it is not the sole solution. One expert noted: *"The full impact of electrification remains uncertain—while it offers many advantages, it's not a universal solution"* (Interview5). Transitioning away from ICE vehicles is only part of it. As another expert highlighted, *"Cutting back on ICE vehicles is a step in the right direction, but the most responsible approach would be to reduce overall mobility. Changing how we drive is crucial"* (Interview6).

Apart from battery electric vehicles, hydrogen is increasingly being discussed as a potential game-changer in the automotive and transportation sectors, with experts being very divided. While some see hydrogen as a natural evolution for the industry, others express concerns about the technical and infrastructural challenges it brings.

A positive outlook highlights hydrogen's alignment with existing fuel infrastructure. *"The EU lacks the necessary materials for battery production, which is steering us toward hydrogen as a more natural progression. There are also many parallels between traditional fuel systems and hydrogen fuel pumps"* (Interview3-2). In specific contexts like cargo shipping and larger vehicles, hydrogen emerges as a superior option to electric power. An industry professional noted, *"Hydrogen offers a strong alternative to electricity, particularly for city buses, trains, and ferries, where it excels due to the lack of charging delays and zero*

emissions. For example, it's impossible for electricity to power a ferry, but hydrogen can solve that" (Interview5).

Although there are benefits for specific applications, its broader adoption depends on addressing infrastructure issues, as well as incorporating it into a comprehensive energy strategy. Early hydrogen infrastructure investments failed due to lack of demand, highlighting the risk of premature green investments. *"We installed Slovenia's first hydrogen station in 2016, but we closed it because there were no hydrogen cars available"* (Interview3-2).

Challenges, especially related to energy consumption and storage, still remain. *"Hydrogen is interesting; in my opinion, it is better than batteries. However, because it involves huge amounts of energy, we do not know how it will be stored"* (Interview6). Additionally, some highlighted that most of the hydrogen currently produced is far from environmentally friendly. *"The thing is that most of the hydrogen is not green. It's even more absurd than the batteries. But if it's subsidised, it's a different story"* (Interview2-1).

Hydrogen is a promising yet very complex component of the future energy landscape. "*Production must advance significantly" (Interview8-2).* Despite technological advancements and ongoing development, the target still feels out of reach. As one industry professional noted: *"Hydrogen is tough because when I started in this business more than 15 years ago, it was a few years away and now it is still the same.. It's always a few years away"* (Interview1). The development of hydrogen technology requires a long-term perspective. *"We need to take hydrogen for the long term. If we are doing something for the environment, hydrogen is an absolute winner, even if electricity is more of an instant solution"* (Interview5).

Even though perspectives are different, industry professionals highlight that no single technology may provide a comprehensive solution, but rather a blend of hydrogen, batteries, and traditional fuels could address various needs. "*The future is likely in a combination of all three methods"* (Interview8-2).

4.3 The role of regulation and policies in the green transition

The discussion covered how EU regulations impact the automotive industry and how Europe compares to the US and China in this regard.

The European Union's leadership in environmental regulation has placed its automotive industry at a crossroads. One industry professional noted *"Europe is a bleeding edge of environmental regulations"* (Interview1), the ambitious policies are causing significant challenges for automakers. Manufacturers must comply with stringent rules, knowing that *"moving away from these targets could cause significant issues"* (Interview1).

A key challenge for European industry is the inconsistency of regulatory frameworks and financial support. When the EU creates a policy, it typically causes significant disruption for businesses. While complying with these regulations can be challenging and manufacturers may sometimes be uncertain about how to meet the requirements, it is still preferable to the uncertainty of not knowing what will happen next. *"In Europe, subsidies are introduced in one country, then shifted to another, only to be withdrawn later. This inconsistency makes it difficult for industries to establish stable and successful businesses. We need more predictable and reliable framework conditions"* (Interview9). As another industry expert noted, *"now that they announced they will allow synthetic fuels, some of the OEMs are saying no, don't change it because we've already invested heavily in one direction. If others haven't, they're at an advantage"* (Interview1).

This constant shift in regulatory expectations has led to a loss of trust in the regulators, leaving businesses uncertain about how to respond to these changes: *"So do I trust that and invest, or do I wait for a potential reversal? It is a huge problem for us. What OEMs are currently asking for is to not change the rules. Set the rules and leave them"* (Interview1). The challenge of uncertainty is further exacerbated by the fact that some regions or countries do not face the same obstacles and can be therefore more competitive: *"China sets a plan and follows it, North America remains flexible with a hands-off approach, while the EU focuses heavily on regulation, making it difficult for businesses to move forward"* (Interview9).

There are many questions about the implementation of regulations. *"The guidelines are on point, but I question how well they are communicated and implemented. Overly strict rules stifle innovation"* (Interview4-2). Industry experts also argue that the EU's approach to enforcement is counterproductive. "*We've leaned too much into coercion. Providing incentives instead of penalties could have achieved similar results. Penalties often backfire, and it seems likely this will too. Change should feel like evolution, not imposition"* (Interview4-2).

Additionally, some industry experts view certain EU decisions such as ban of ICE vehicles as without broader consideration of cause and effect. *"The 2035 ban on ICE vehicles is an overreach. If only Europe adopts it, the impact will be negligible"* (Interview2-1). Without global alignment, such initiatives risk harming the EU economy while yielding minimal environmental benefits. *"EU policy is killing the automobile industry"* (Interview7).

A recurring concern is the mismatch between global competition and EU-specific regulations. *"Regulations put us on a different playing field, but the market operates globally. Other regions have lower costs, putting the EU at a disadvantage"* (Interview5). While European producers adhere to stringent policies, Chinese vehicles are becoming increasingly competitive. *"The main difference between China and Europe is regulation. Strict policies are probably suffocating us. Chinese vehicles are on a par with European ones, except that they are cheaper"* (Interview4-1).

There are certain regulations with which producers are struggling to comply. *"Euro 7 is coming. It restricts particle emissions from brakes and tires, I think. I'm not sure about tires, but brakes, definitely. And that's a huge shock for the industry because you cannot solve it with existing solutions"* (Interview1). As a result, manufacturers must shift their focus toward unexpected challenges and develop new solutions to meet these regulatory demands.

The regulatory disparity between regions is further highlighted by the materials used in production. While Europe enforces rigorous standards, such as mandatory use of recycled materials, China faces no such restrictions. *"China, for example, has no such regulations and uses non-recycled materials. It's harder to work with recycled materials, as they tend to be inferior. Our competitiveness is therefore declining"* (Interview5).

Some experts voice concerns over the unintended consequences of current regulations. A recurring criticism centers around the disconnect between regulatory objectives and their real-world impacts. One industry expert highlighted a striking example: *"Since we no longer produce aluminum domestically, we have to rely on imports, resulting in a significantly higher carbon footprint. Yet, regulators still consider this approach greener"* (Interview6).

Criticism also extends to the broader strategic direction of EU policies. *"In my opinion, we're heading entirely in the wrong direction. It's a path designed for the country, not for the people"* (Interview7), one industy professional mentioned, pointing out the perceived misalignment between high-level sustainability agendas and their impact on individuals. A key driver of these issues, according to another perspective, is the EU's inability to explore alternative paths due to a lack of expertise. *"The EU follows a single path because we lack the expertise to explore alternative directions"* (Interview1).

4.4 Supply chain challenges and its implications

The European automotive industry faces growing concerns about supply chain stability and resource independence. Rising costs and reliance on foreign suppliers are forcing manufacturers to rethink their sourcing strategies.

Currently, the percentage of supplies coming from China is at an all-time high. However, *"without sourcing materials from these markets, it's nearly impossible to stay competitive in Europe due to high costs"* (Interview9). This reliance on foreign suppliers highlights a fundamental dilemma: cost efficiency versus supply chain resilience. Global trade is driven primarily by price rather than fairness and sustainability. As a result, *"European producers are forced to buy components and materials from China because it is cheaper"* (Interview9). *"The majority of battery materials come from China, making production entirely dependent on them. It is only a matter of time before China also advances in metal and steel production"* (Interview8-2). This growing dependence raises concerns about future supply

chain bottlenecks and the potential geopolitical leverage that China could achieve over the European automotive sector.

Some industry professionals argue that Europe is missing an opportunity by focusing exclusively on certain technologies instead of exploring alternatives. *"If the EU does not engage in mining, other countries will"* (Interview5). While concerns about environmental impact persist, there is also recognition that *"although mining would have significant consequences, we still need to be more self-sufficient"* (Interview4-1). This lack of self-sufficiency is evident in the most crucial materials needed for automotive production. *"Even the aluminum for the cars we are not able to produce by ourselves"* (Interview2-1).

A big problem are sustainability targets. *"If we all agree on reducing the carbon footprint and all people in the world do it, then we could source from Europe"* (AUTO9). This means that achieving a more sustainable supply chain would require a global commitment. Without such a shift, lower-cost producers will continue to dominate the market, leaving sustainability concerns secondary to price competition. A clear example of this dilemma can be seen in the following example: *"We spoke with a company that used to import high-quality steel from Germany. Now, due to cost pressures, they import lower-quality steel from China. However, transporting it from China results in four times the CO_2 emissions compared to sourcing it locally in Germany"* (Interview9).

A major point of concern is the lack of a long-term strategy to secure key raw materials within the EU. *"A responsible approach means keeping essential resources domestically. Currently, there is no long-term strategy—only short-term economic considerations. Policies, including taxation, could help regulate this, ensuring key raw materials remain within the EU"* (Interview4-2). The challenge of securing a stable supply chain extends to the EU's EV targets as well. Without addressing sourcing issues, achieving these goals remains unrealistic: *"Meeting the demand for EVs by 2030 is unrealistic, as production remains heavily reliant on imported components"* (Interview2-1).

Given these constraints, prioritizing the reuse of existing materials over new extraction would be a more sustainable approach. As one expert emphasized. *"In terms of sustainability, which is a huge topic in the EIA mobility, I think the best topic is really recycling and to create a chain in terms of not producing, but trying to use what is already there"* (Interview2-1)

As the EU continues to push forward with its ambitious sustainability goals, industry experts warn that without a comprehensive and forward-thinking strategy, Europe risks losing its competitive edge. Ensuring supply chain resilience, diversifying energy investments, and securing access to critical materials will be crucial in shaping the future of the automotive sector.

4.5 Technology and autonomous driving

In the race toward self-driving cars, Europe is taking a cautious approach. Technology in Europe is heavily shaped by regulatory frameworks, much like those in the transition to electric mobility, where ambitious policies often introduce barriers and complexities for manufacturers. "*Europe is limiting the adoption of advanced driver-assistance systems because of strict regulations"* (Interview1). For example, companies like Tesla offer vehicles in the US with a wider range of autonomous driving capabilities, but these same features are often restricted or disabled in Europe due to compliance requirements. *"When you buy a Tesla in the US, it can do all sorts of things. In Europe, it's not allowed"* (Interview1).

In EU, there are many concerns about data protection, which are slowing the development of autonomous vehicles. Unlike China, the EU's strict regulations on data privacy might make it the last to fully embrace self-driving technology. As one industry professional put it, *"Compared to China, we have a lot more freedom, which is an advantage for the people. However, this freedom comes at the cost of slower innovation in this area"* (Interview7).

In Slovenia, the challenge is even more fragmented. The country's approach to autonomous driving is far from unified. *"Unfortunately, we are not developing such a system in Slovenia; each municipality works in its own way"* (Interview6). This decentralized approach makes it difficult to create a nationwide strategy or infrastructure for autonomous vehicles, leaving the country behind in this technological race.

One of the major hurdles for the future of self-driving cars, regardless of location, is also the infrastructure needed to support them. Autonomous vehicles generate massive amounts of data, which requires systems capable of processing and analyzing it in real time. *"The future of autonomous driving depends on the infrastructure, which will need to be able to process all the data"* (Interview4-2). Without this infrastructure in place, self-driving cars cannot reach their full potential, regardless of the regulatory environment.

The adoption of fully autonomous vehicles in Europe faces significant regulatory and legal hurdles, particularly concerning liability in the event of an accident. Unlike traditional vehicles, where responsibility falls on the driver, autonomous cars raise complex legal questions about who should be held accountable—the car manufacturer, the software developer, or the owner. One interviewee highlighted this challenge, stating: *"A fully autonomous car making an accident—who is responsible? This is why it will take a long time in Europe"* (Interview7).

4.6 Discussion

The competitiveness of the Slovenian and European automotive industries is increasingly challenged by both internal weaknesses and external pressures. The main empirical findings of the study are presented in Table 8.

Germany, the EU's leading automotive powerhouse, has experienced a steady decline in its global market share since 2011, despite occasional rebounds. Data analysis reveals that not only has Germany's share of automotive exports shrunk in value, but its overall vehicle production and sales volumes have also declined. More broadly, Europe produced fewer cars in 2023 than it did two decades ago—a troubling trend given the continuous rise in global vehicle production. The gap between China and Europe in vehicle sales is even more pronounced in the electric vehicle sector, where China has taken a commanding lead. Based on current performance, Europe shows little sign of closing the gap anytime soon. Industry experts remain highly skeptical, largely because competing with China's significant cost advantages presents a major challenge for European manufacturers.

The European decline in competitiveness is driven by a combination of regulatory challenges, industrial policies, and external market forces. While the EU has made electrification and sustainability key priorities, its stringent regulations often impose high costs, create uncertainty, and therefore hinder the industry's ability to remain competitive. Frequent regulatory changes contribute to instability and make it difficult for manufacturers to plan long-term strategies. Some companies have been forced to make premature investments in adapting to new standards, while others have delayed decisions due to uncertainty, which leads to an uneven playing field.

Additionally, European policies also present contradictions. While aiming to meet climate targets, they often fail to consider the broader economic and industrial impact. Experts acknowledge that electrification is a step in the right direction, but the way it is being implemented creates significant challenges. Regulations dictate not only the direction of the industry but also material sourcing, cost structures, and supply chain dependencies. As a result, Europe has become highly reliant on China for critical raw materials such as battery components and key metals. This raises serious concerns about the long-term sustainability of the EV transition, as securing raw materials remains a critical factor for success. Industry experts emphasize that such heavy reliance on external sources is unsustainable. When market conditions shift, the lack of alternative supply options leaves little room for flexibility, putting the entire industry at risk.

At the same time, Chinese manufacturers benefit from lower production costs, strong government support and dominance in battery production and supply chains, which makes it increasingly difficult for European and US manufacturers to compete. Unlike Europe, where policies are fragmented and regulatory framework is frequently changing, China has strategically aligned policies that foster growth.

Given the current industry trend of transitioning to electric vehicles, Europe is losing. The shift to EVs has not progressed as planned, largely because it is being driven by regulatory mandates rather than natural market demand. Insufficient charging infrastructure, high production costs, and affordability concerns have further slowed adoption. Manufacturers remain cautious due to the low profitability of EVs, while consumers are hesitant because of high prices and doubts about driving range and convenience. Industry professionals recognize that European consumers are reluctant to pay a premium for EVs and are especially concerned about driving range and convenience. Consumer research reinforces this, revealing that Chinese consumers are more willing to invest in advanced technological and autonomous features. This disparity poses a significant challenge to accelerating EV adoption.

However, even if consumer demand were to increase, experts warn that the existing energy infrastructure would struggle to support the surge in electricity demand. Additionally, hydrogen—another key trend in the future of mobility—requires substantial investment before it becomes a viable alternative. While data and expert interviews suggest that hydrogen has strong theoretical potential, particularly for heavy-duty vehicles, it is unlikely to be a practical solution in the near future.

Beyond electrification, Europe faces additional challenges in the race toward autonomous driving. Again, as with green transition, strict regulatory frameworks, particularly concerning data privacy and liability, slow down the adoption of self-driving technology. While companies in the US and China push forward with fewer restrictions, European manufacturers face compliance barriers that limit the deployment of advanced driver-assistance systems. In Slovenia, the situation is even more fragmented, with a lack of coordinated national strategies hindering progress. Furthermore, the success of autonomous vehicles is heavily dependent on infrastructure capable of processing vast amounts of real-time data—an area where significant investment is still needed. Without addressing these regulatory, legal, and infrastructural challenges, Europe risks falling behind in yet another key automotive innovation.

Considering these factors, neither Europe nor Slovenia appears to be well-positioned for the ongoing transformation in the automotive industry. Slovenia, despite its high-quality production capabilities and strong expertise, remains highly vulnerable due to its small market size. High taxes, rising operational costs, and limited government support further undermine its ability to compete. Without more strategic and coordinated efforts at both the national and EU levels, the region risks losing further ground in the global automotive sector.

It is difficult to determine whether the industry is moving in the right direction, but empirical studies clearly show that the regulatory environment does not provide the support automotive manufacturers need to thrive. However, European institutions seem to recognize these challenges and have begun developing strategies aimed at benefiting both the EU as a whole and Slovenia as part of it.

Table 9: Key empirical findings

Topic	Key empirical findings	Relevant research question(s)
Competitiveness of Slovenian and European automotive industry	Slovenia has a high-quality production and a lot of expertise, but small-scale operations and dependancy on Germany lead to vulnerabilities.	RQ1, RQ2
	Slovenia's competitiveness is weakened by high taxes, rising costs, and insufficient state support.	RQ1, RQ2
	Europe can hardly compete with Chinese manufacturers, as they are faster and more cost-effective.	RQ1
	Slovenian producers should diversify or work with China instead of competing with it.	RQ2, RQ4
Electric vehicles	Main problems for feasibility of EVs are energy and infrastructure.	RQ3
	EV adoption in EU is low, both because the discouraged buyers as well as producers, which struggle with lower profitability of EVs.	RQ3
	Transition toward EVs is run by regulation requirements and incentives rather than a natural shift.	RQ3
	China leads in EV production due to lower costs, strong state backing, and fewer regulatory barriers.	RQ1, RQ3
Hydrogen	Hydrogen has long-term potential especially for heavy-duty vehicles and cargo shipping.	RQ4
	Significant investment is required, current storage and production methods remain costly and not fully sustainable.	RQ3, RQ4
Regulation and EU policies	Strict regulations impose high costs and create challenges for manufacturers.	RQ1, RQ3
	Regulatory pressure reduces competitiveness and limits operational flexibility.	RQ1, RQ3
	Frequent regulatory changes create instability, distrust, and market inequalities.	RQ1, RQ3
Supply chain and its implications	Europe heavily relies on China for key materials like battery components, metals, and aluminum.	RQ1, RQ4
	Sustainability concerns force companies to source from other regions (China) and therefore become more dependent on them.	RQ3, RQ4
	The absence of a comprehensive plan for securing raw materials makes EV targets harder to achieve.	RQ3, RQ4
	A stronger focus on recycling and material reuse could improve sustainability and reduce reliance on imports.	RQ3, RQ4
Technology advancements	EU will be the last to have autonomous vehicles due to data privacy concerns.	RQ4
	Slovenia does not have a clear strategy for autonomous vehicles.	RQ2, RQ4
	Europe currently does not have the required infrastructure.	RQ4

Source: Own work.

5 CONCLUSION

The automotive industry has been crucial to Germany and Europe, but its global dominance is fading. China's rapid rise is outpacing traditional leaders, pressuring European brands as their value declines. While the US also struggles to keep up, its economy is less reliant on the sector, making the impact less severe. China holds significant advantages across nearly every aspect of the industry, particularly in supply chain independence and battery manufacturing expertise. These strengths allow Chinese manufacturers to capitalize on economies of scale, lower production costs, and strengthen their global competitiveness—further reinforced by a work ethic that prioritizes efficiency and speed. In terms of industry trends, China is leading the way in electric vehicle sales, leaving Europe trailing behind with more modest adoption rates.

However, several limitations must also be acknowledged, as they may influence the interpretation of this study's findings. A primary challenge was the lack of complete and consistent data, particularly for China, along with notable gaps in sector-specific information. Inconsistencies in industry classification across data sources further complicated cross-regional comparisons. Moreover, the automotive sector is undergoing rapid transformation, driven by geopolitical developments, shifting trade dynamics, and evolving policy landscapes. As such, some of the data may already be outdated or may not fully reflect current industry development. Future research should therefore consider the accelerating impact of emerging trends, all of which are reshaping the global automotive industry.

The technological gap is also widening, particularly in the area of autonomous driving, where both the US and China continue to set the pace. Consumer behavior further reflects this divide, with Chinese consumers more eager to embrace connected vehicle features than their German counterparts. Industry experts are increasingly concerned about the trajectory of Europe's automotive sector. While countries like Germany and Slovenia have a strong reputation for high-quality manufacturing and technical expertise, a range of internal and external challenges are stalling progress. The ongoing energy crisis and supply chain disruptions—many linked to ambitious sustainability targets—are among the most pressing concerns. A significant issue raised by industry professionals is the disconnect between regulation and real-world industry needs. European policymakers frequently introduce new regulations without fully considering their broader impact, creating uncertainty and additional costs for manufacturers.

One of Europe's biggest disadvantages compared to China is the inconsistency of its regulatory framework. While China sets clear policies and follows through with them, European regulations are constantly changing, making it difficult for businesses to plan long-term. These frequent regulatory shifts affect everything from raw material sourcing to production processes, leading to increased costs, lower profitability, and greater hesitation

in transitioning fully to EV production. Compounding these challenges is Europe's heavy reliance on Chinese raw materials, making the region highly vulnerable to supply chain disruptions. All of these issues are jeopardizing its competitive standing in the global market.

In conclusion, without rethinking the strategy to make supply chains more independent, regulations more manageable yet effective, and fostering technological innovation to drive progress, European automotive industry is at risk of losing its competitive edge entirely, falling permanently behind its global rivals.

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APPENDICES

Appendix 1: Interview questionnaire

Current position of Slovenian automotive industry

- How do you see the current position of Slovenian automotive industry?
- What are the mobility trends that Slovenian automotive companies are betting on?
- From your perspective, how is the industry in Slovenia uniquely positioned within the broader European context?
- What is Slovenia's added value in the new mobility trends?

Sustainability and e-mobility

- What are the biggest trends in e-mobility and sustainability in automotive industry?
- How is the ongoing shift towards electric vehicles (EVs) influencing your product development/business?
- Do you have any internal ESG policies/sustainability goals and if so how do you measure and implement them?
- Do you see any potential for hydrogen in the Slovenian mobility sector?
- Do you think Slovenia is well equipped for such transition (infrastructure, know-how, technology)?
- How do we compare with Austria and Germany as well as global environment?
- Where do you see biggest challenges for e-mobility and what opportunities do you see for sustainable automotive technologies?
- What is the role of public transportation, car sharing, etc. in the future of mobility?

Technology trends and innovation

- How do you see these emerging technologies shaping the future of the automotive industry?
- What are your predictions for the adoption of autonomous technologies in the market?
- How do you foresee the role of connectivity and software in the future of vehicles?
- What steps are you taking to integrate these technologies into your products?

EU regulation and policy

- What is your opinion on EU regulation of mobility compared to other regions worldwide (US and China)?
- Do you think EU regulation promotes the right idea of sustainability?

- What changes should Slovenia make to bring e-mobility closer to businesses and consumers?

Supply Chain and Economic Resilience

- Given the recent global supply chain disruptions, how are you enhancing the resilience of your supply chain?
- How are you achieving the stability of your supply chain considering the majority of raw materials (Lithium, etc.) need to be imported (mostly from China)?
- Where do you see the biggest challenges and what are the trends for solving them (if any)?