THE ROLE OF INNOVATION MANAGEMENT AND TECHNOLOGICAL DEVELOPMENT ON THE EFFICIENCY AND COMPETITIVENESS OF INDUSTRIAL ENTERPRISES.

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Abstract. The current report examines technological development and innovation management in the field of microelectronics, considering the impact of technological innovations on the industry in light of global challenges such as digitization, economic turbulence, and the need for reorganization of production capacities in accordance with the new regulations of the EU.
The aim of the study is to present effective and optimal solutions and approaches that foster sustainable growth and competitiveness in the microelectronics sector. The methodology includes assessing the role of strategic innovation management in enhancing efficiency and competitiveness through the swift and flexible implementation of technological innovations. Additionally, it involves applying market segmentation methodology to the microelectronics market by sectors to analyze consumer behaviour and evaluate the impact of investments within a dynamic economic environment with limited production factors.
The results of the report provide significant insights and recommendations for the sustainable development of companies in the sector, emphasising the connection between economic growth and sustainability in microelectronics.
Keywords: economic growth, sustainability, microelectronics, innovation.
JEL: O32; O33; L63; O11

1. Introduction:

In the dynamically changing environment of the 21st century, understanding the factors contributing to sustainable economic growth is more relevant than ever. The global economy faces numerous challenges, including technological changes, globalization, climate change, and socio-economic imbalances. In this context, industrial enterprises play a critical role in stimulating economic growth, creating jobs, and promoting sustainable development.

This scientific research focuses on the analysis of management, innovation, and technological development in industrial enterprises, aiming to uncover how these factors contribute to increasing the efficiency and competitiveness of the sector. Significant emphasis is also placed on strategies to reduce the ecological footprint and integrate sustainable practices, which are essential for achieving a balance between economic growth and environmental

conservation. Identifying these components and developing innovative solutions is crucial for overcoming future challenges and promoting a greener and more sustainable economic model.

The interest in industrial enterprises as drivers of economic growth and sustainability is motivated by their ability to adapt to changing global conditions and to implement innovative technologies and management practices. In the modern era of sustainable development, industrial enterprises are at the forefront of the transition to a green economy through the implementation of energy-saving technologies, resource recycling, and the development of environmentally friendly products.

This topic is particularly relevant in the context of growing public and political pressure to take action against climate change and protect the environment. Moreover, the analysis of industrial enterprises defines significant opportunities for innovation and optimization of production processes, which can improve efficiency and reduce operating costs.

The methodology of the present study utilizes the toolkit of economic statistics as the primary scientific approach for analyzing and assessing events and dynamics in the socio-economic relationship. Key analysis tools include descriptive statistics, graphical analysis, and analysis of findings and conclusions.

Assumptions and premises in the scientific research:

- The dynamics of the following indicators are examined: company turnover, profit, units produced, production capacity, and investments.
- Over a time frame of 5 years starting from 2019 to 2023.

The subject of the study will be semiconductor manufacturers in Europe and globally. The relationship between electric vehicle manufacturers and semiconductor investments, as well as market trends in Europe and Asia, will be explored. Analysis of global capacity and potential economies of scale will be conducted, encompassing semiconductor imports into Europe and their effect on the economy.

2. Empirical analysis.

The analysis of the role of digitization presented in this structural section of the development reveals the impact of the microchip shortage on the microelectronics sector. The economic demand for chips and electrification on national, regional, and international levels has led to an increase in the sector's volume over the past 5 years.

Figure 1 depicts the dynamics of sector revenues on a global scale over the same period.

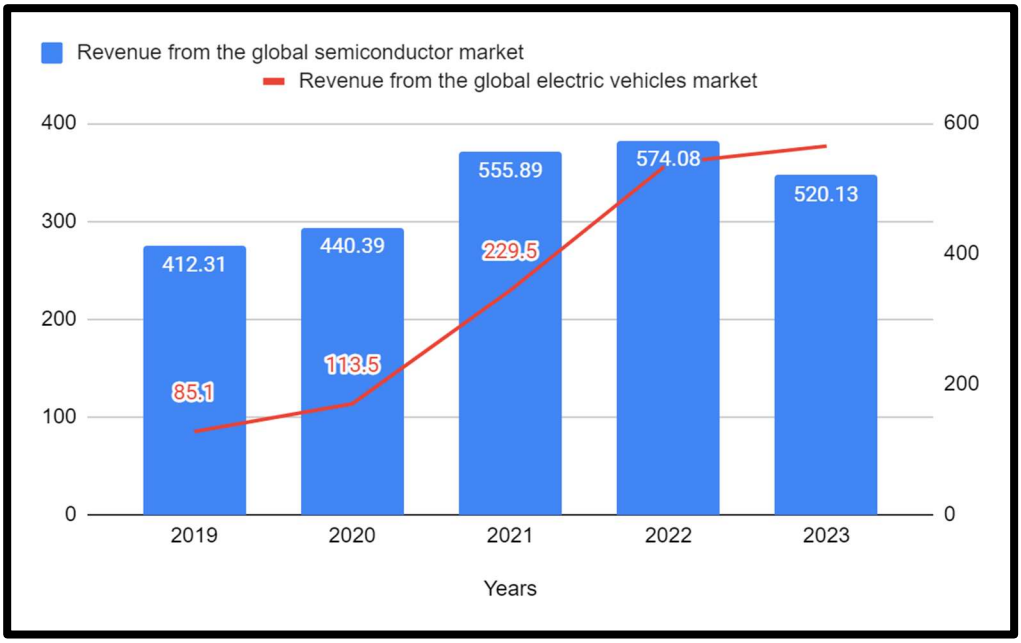

Figure 1 Semiconductor Market Revenues Worldwide from 2019 to 2023 (in billion U.S. dollars).
Source: https://www.statista.com/.

The results from the presented graph show an increase in sector revenues in absolute value from 2019 to 2023 worldwide. Fig. 1 clearly demonstrates a pronounced upward trend in the presented time series with several moments of stagnation characteristic of periods of economic instability. Comparing the changes for the studied period in absolute value, it amounts to $555.36 billion.

Numerous scientific studies and experts warn about the microchip market problem, but it is not evident from the shown trend. By tracking the trends in recent years, the subsequent Fig. 2 illustrates chip sales only for Europe on a quarterly basis for the past 5 years.

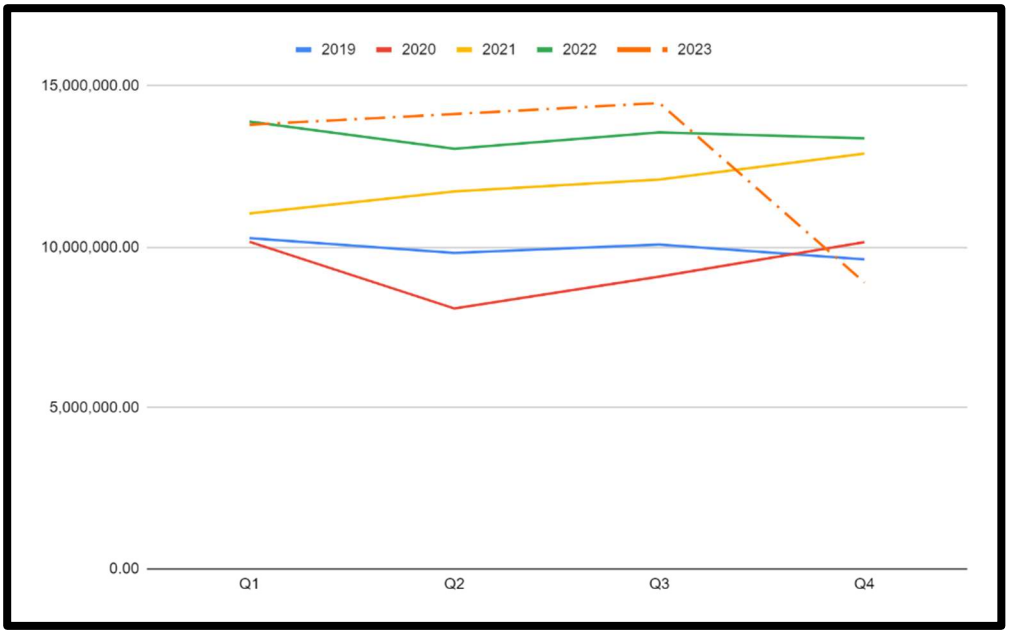

Figure 2. Chip Sales in Euro, Europe.
Source: https://www.statista.com/.

Fig. 2 The significant decline observed between the third and fourth quarters of 2023 undoubtedly represents a notable deviation from the established growth trend characteristic of the period from 2019 to 2023. Over the preceding five years, the industry demonstrated extremely positive dynamics without similar declines, making the current quarter particularly interesting for scientific research.

The question of the causes and potential strategies to overcome this decline sparks considerable academic interest. Analysis focused on sector breakdown provides an opportunity for a detailed examination of consumer behavior in different areas.

Fig. 3 illustrates the distribution of chips by industry in percentage terms worldwide in 2023. The data from the figure reveal the key role of the automotive industry and industrial applications sectors in the chip market. The industrial applications sector is witnessing increased interest driven by the digitization expansion, which encompasses technologies such as solar panels, hence the significant expansion observed in electric parks in recent years. Additionally, strict European environmental regulations and green energy requirements actively promote investments in this segment, fostering the demand for innovative solutions.

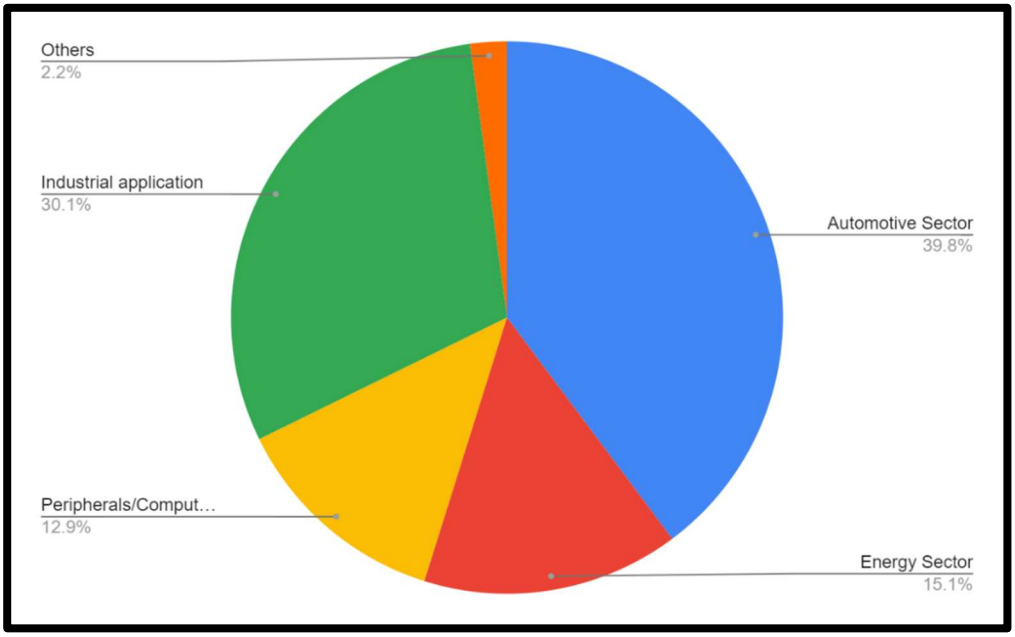

Figure 3. Percentage Distribution of Semiconductor Investments by Economic Sectors for the Year 2023 on a Global Scale in %.
Source: https://www.eusemiconductors.eu/esia

On the other hand, the market for electric vehicles and hybrids has significantly increased in recent years. While conventional cars require about 400 chips for production, the production of electric vehicles raises the demand to values above 3000 chips, representing an increase of 650%. This deepens the need for chips in the automotive industry and is a leading factor in driving demand.

The challenge for automotive manufacturers is to reduce energy consumption and increase the range of electric vehicles. To achieve this, vehicles are equipped with complex energy management systems that require a significant number of chips.

Forecasts for chip market growth until 2030 are favorable, especially due to rapid electrification. Following the economic principle of economies of scale, the majority of manufacturers have increased their investments in production capacity to ensure a competitive advantage.

Despite the slight market fluctuation during the pandemic, rapid recovery is observed post-Covid-19 and its economic consequences. Forecasts indicate that this growth may not continue with the same intensity into the beginning of 2023.

The slowdown in the growth of the sector is partly attributed to the decision made by the European Commission in 2023 to extend the production of diesel and gasoline vehicles until 2035, as the world is not yet prepared for

a full transition to electric vehicles. Consequently, consumer behavior changed, and instead of continuing the trend of purchasing hybrid and electric vehicles, people reverted to diesel vehicles due to the possibility of using them for another 11 years and, of course, to save part of their income.

Figure 4 depicts the change in revenues from electric vehicles in a dynamic manner for the period from 2019 to 2023.

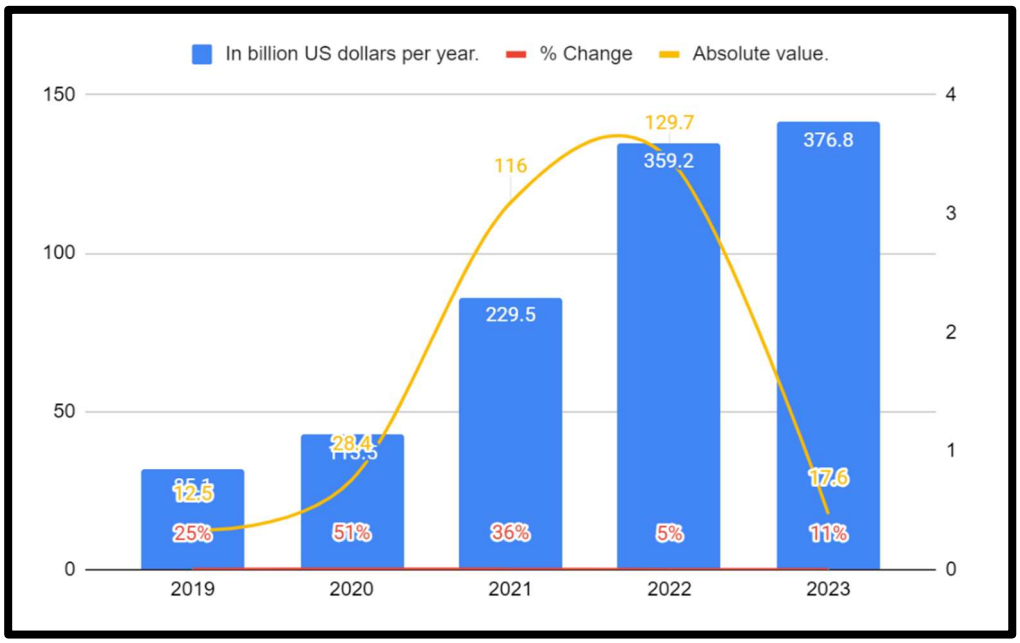

Figure 4. Revenues of the global electric vehicle market between 2019 and 2023 in billion U.S. dollars.
Source: https://www.statista.com/

In Fig. 4, the increase in revenues from electric vehicles during the period from 2019 to 2023 is depicted. In absolute numerical values, a notable surge is observed, starting from $12.5 billion and reaching $129.7 billion. This analysis emphasizes the importance of changes in the automotive industry and the impact of electric vehicles on economic dynamics. The observed growth during this period is a result of changes in consumer preferences and efforts to develop more environmentally friendly technologies.

It's remarkable to see the significant growth up to 2022. The results of the conducted research clearly indicate that industrial enterprises have sustainable sales growth expressed with stable changes in absolute values, even with a decrease in the percentage increase. The increase in accumulated monetary capital over the years is evident, but we notice that the rate of change in absolute value decreases, and the percentage change from year to year experiences a strong pronounced jump, after which it stabilizes at a relatively

consistent level. This fact undoubtedly confirms both the absence of a decline in demand and the relevance and significance of the sector in economic terms. The conclusions drawn reveal the need for further research to extract details regarding the factors contributing to the sustainable economic development of the sector.

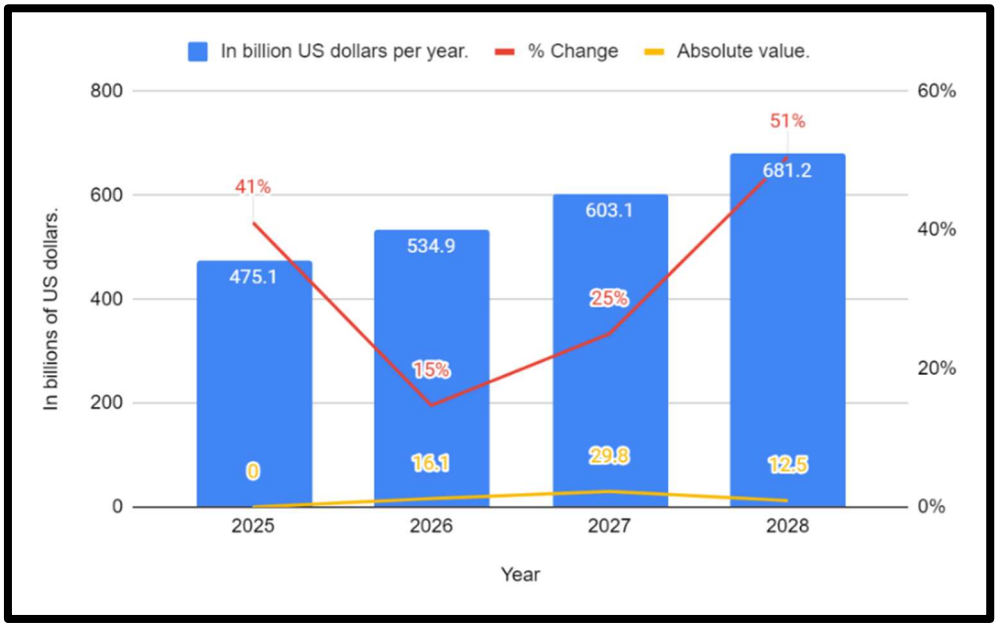

Figure 5. Forecasts for revenues of the global electric vehicle market between 2025 and 2028 in billion U.S. dollars.
Source: https://www.statista.com/

The forecasted revenues from 2025 to 2028 indicate that the electric vehicle market will continue to grow despite an expected downturn in 2026 by a few percentage points, with no significant deviations observed. Instead, there will be a smooth growth ranging from 16% to 30% annually. This suggests that the market will sustain its growth trajectory despite geopolitical factors. Since we are dealing with a global factor, many questions arise regarding how this growth will be distributed globally and what the effect will be for Europe.

Moreover, we need to investigate whether there is a connection between the manufactured cars and the semiconductor chips invested in them, leading to an increase in revenues in the semiconductor sector. To conduct a thorough analysis, we will undertake a comparative study of electric vehicles produced globally. This study will consider the significant investment in semiconductor technologies within these vehicles and their simultaneous impact on global revenues.

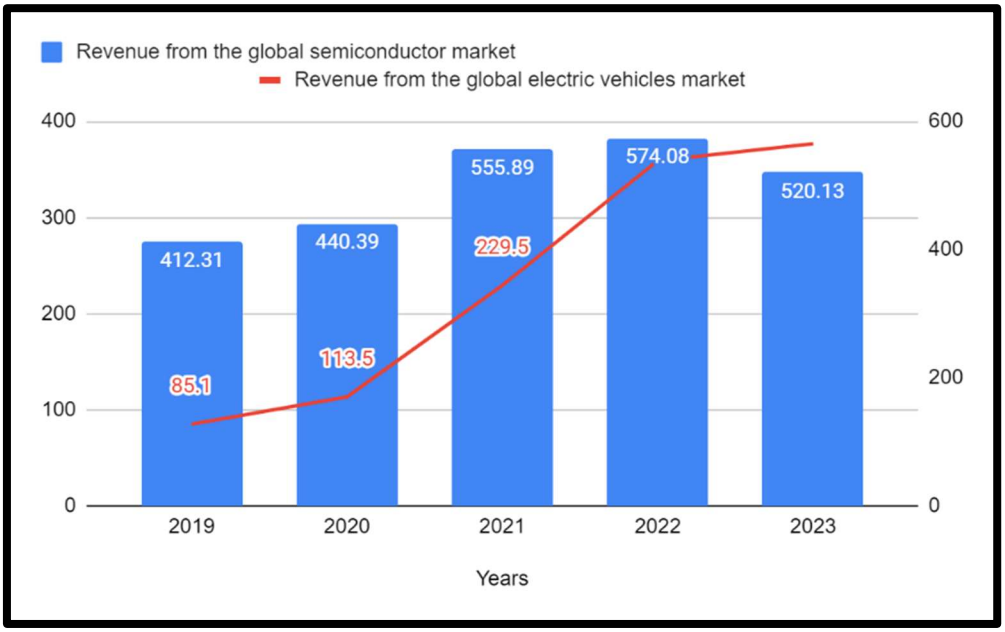

Figure 6. Comparison between semiconductor revenues and sold EV automobiles from 2019 to 2023 globally in billion dollars.
Source: https://www.statista.com/

In Fig. 6, it is very clear that the revenue of the semiconductor market, represented by bars, follows the same trend as the curve of the EV market, with slight deviations, indicating a positive correlation between the data.
The minor deviations can be explained by the fact that the supply chain operates with buffers, and these buffers cause delays at chip manufacturers since Kanban systems are used to regulate and dampen deviations in deliveries and balance inventory levels, as well as noise in the system between different links.

Despite the global trend towards increased chip demand and the growth of the electric vehicle industry, this trend is not as pronounced in the EU. In Fig. 7, it is evident that sales of electric vehicles continue to grow and maintain a positive trend, while semiconductor revenues, after a four-year trend of growth, decrease in 2023. This may be explained by increasing price competition from China and increased imports into Europe.

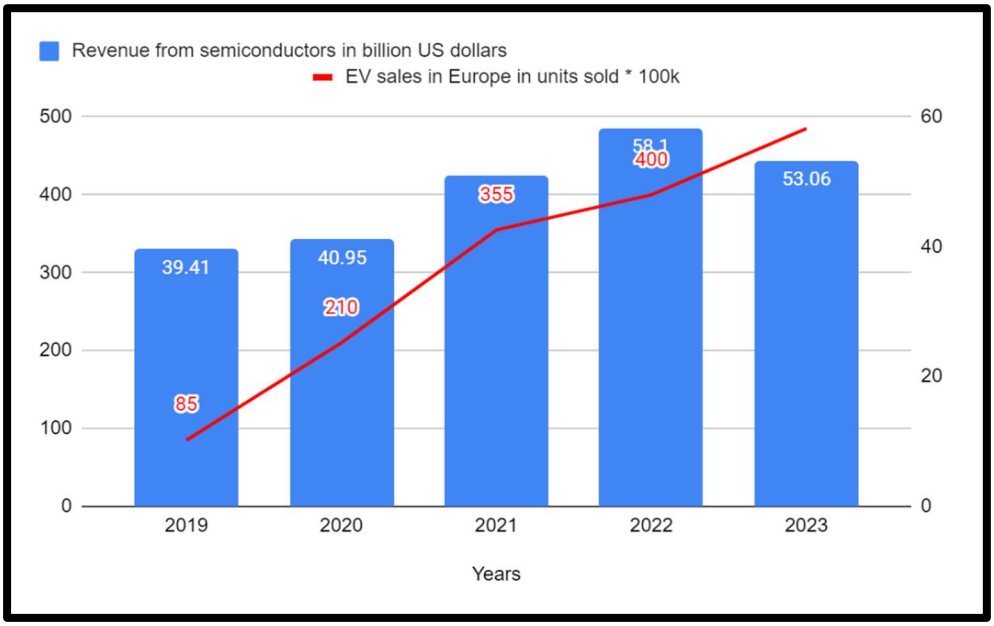

Figure 7 presents a comparison between revenues in billion dollars and the sold EV automobiles from 2019 to 2023.
Source: https://www.statista.com/

In order to answer this question, we will examine the global capacity by country and what the opportunities are for economies of scale and gaining market and price advantage.

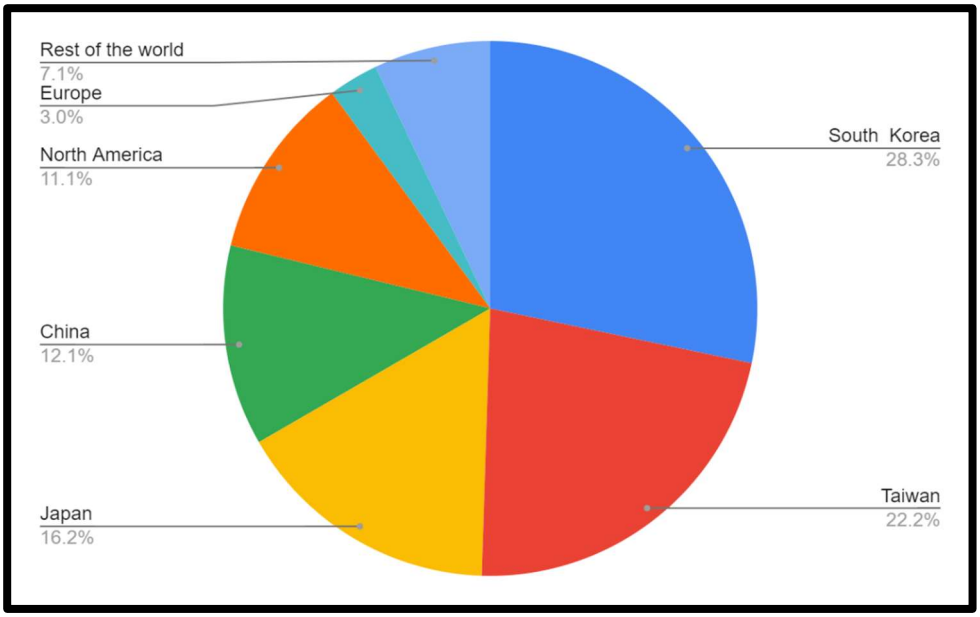

Figure 8. Global semiconductor production capacity in 2023.
Source: https://www.rpc.senate.gov/

In Figure 8, the production capacity of global semiconductor manufacturers is presented, with market share up to 2023. Capital investments in manufacturing facilities require significant financial and time resources. The implementation of innovative technological solutions that drive technological advancement is a key factor in increasing competitiveness. However, the process of adopting new technologies is often slow and requires careful planning, testing, and employee training.

With awareness of the slow investment in new equipment and the complexity of technological innovations, companies are faced with the challenge of adapting to market pressure to reduce prices. One of the strategies they can employ is cost optimization. This strategy involves reducing internal costs to achieve greater efficiency and better utilization of available resources. In the process of cost optimization, companies often focus on downsizing or limiting their workforce and operational expenses. For example, the implementation of automation in certain processes has the potential to reduce the need for manual labor while simultaneously increasing productivity and the accuracy of work actions. Applying software solutions for business process management can also help with more efficient and optimized resource allocation.

Such actions within cost optimization provide companies with the opportunity to quickly respond to market changes and gain a competitive advantage in the short term without significant risks and burdens on their

budget. Although this approach may be beneficial in the short term, sustaining long-term competitiveness requires investments in innovations and technologies that ensure sustainable growth and successful adaptation to future industry trends. Eliminating inefficiencies, reducing staff, streamlining administrative procedures, and implementing artificial intelligence are some of the strategies for securing long-term advantages.

As a result, many companies have begun restructuring their processes and business models to optimize costs, shake up their structure, and focus on efficient resource utilization. One of the main goals is to make quick decisions and take actions without resistance to change. Large companies and their employees face the challenge of transforming sluggish structures into flexible and rapidly adapting organizations.

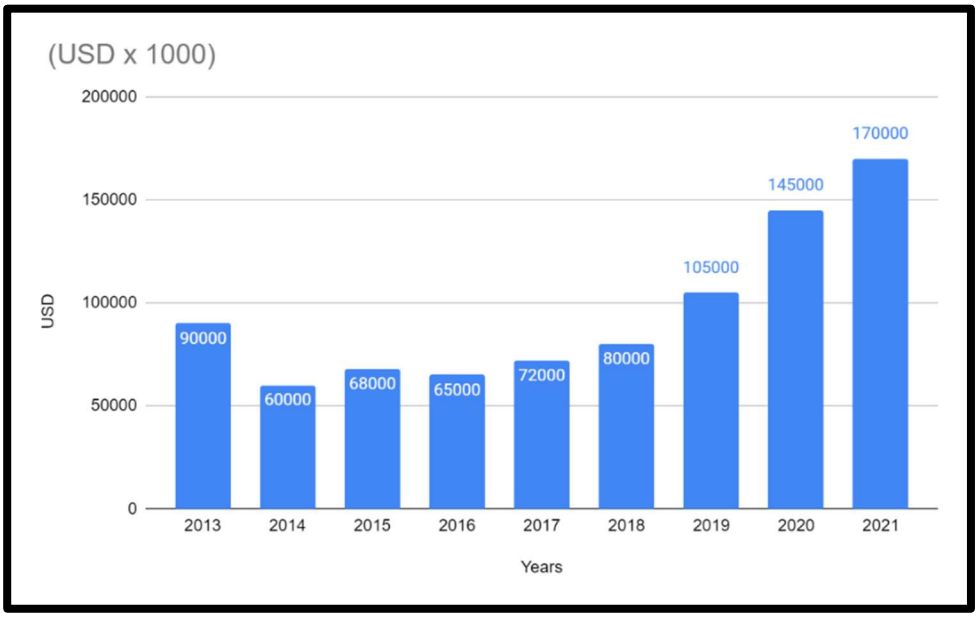

Figure 9. Semiconductor imports from China, 2013-2021.
Source: https://www.examinechina.com/

Figure 9 illustrates that semiconductor imports from China to Europe are increasing, supported by lower manufacturing costs in Asia. The graph also explains why it is becoming increasingly difficult for European manufacturers to maintain their market advantage, even in the European market.

European companies that have been selling to Asia until recently are beginning to lose their competitive edge against local manufacturers in the region. Additionally, the value of the electric vehicle market in China proves to be extremely strong for the year 2023, where BYD even surpasses Tesla in sales growth, which is a clear signal of changes in global market dynamics.

Knowing that there is a direct link between EV sales and semiconductors, increased car sales in China and increased semiconductor imports should have a positive impact on Asian manufacturers and conversely for European ones.

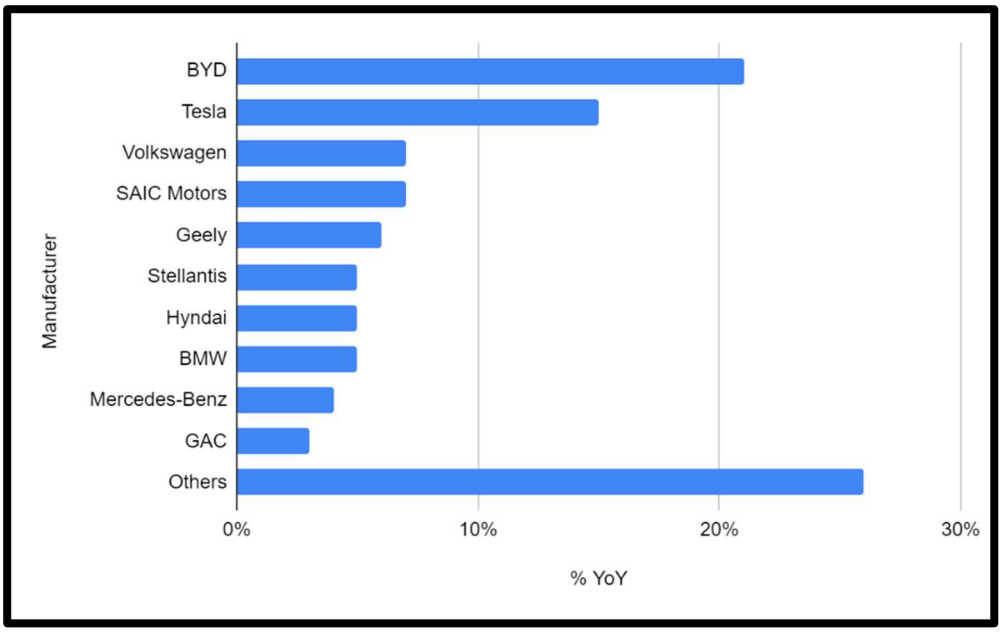

Figure 10 Global sales of electric vehicles (EV) in 2023.*
Source: https://www.canalys.com/

For the first half of 2023, global electric vehicle (EV) sales surged by 49% to 6.2 million units. The EV market is rapidly evolving, with the majority of sales (55%) occurring in Mainland China. Chinese manufacturer BYD also demonstrates impressive sales growth. Global EV sales are expected to increase by another 39% in 2023 (source: canalys.com 2023).

Figure 10 illustrates the growth in electric vehicle production by brands in percentage terms from 2022 to 2023. It's evident that the Chinese manufacturer BYD outperforms the European Tesla. On slides 9 and 10, we established the correlation between the sales of electric vehicles and the invested semiconductors.

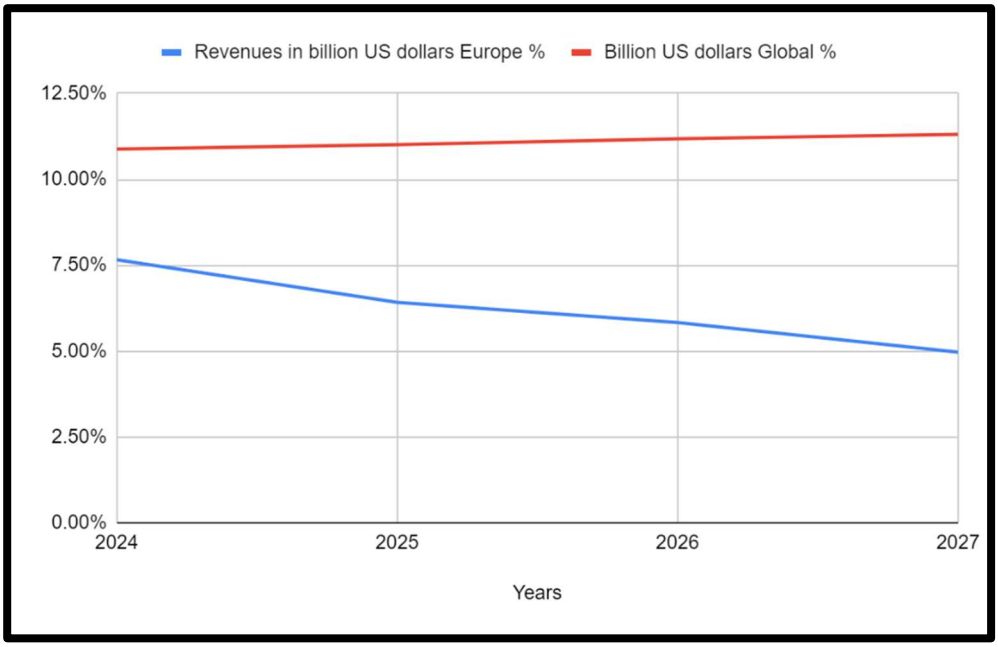

Figure 11 illustrates the forecasted revenues of the semiconductor market in Europe and globally from 2024 to 2027 in billions of US dollars.
Source: https://www.statista.com/

Figure 11 clearly reflects that the forecasted revenue growth rates globally demonstrate a positive trend in percentage terms, despite the observed slight deceleration in growth. At the same time, revenues in Europe also show a positive increase but with a downward trend, nearly 2.5% compared to the beginning of 2024. From this analysis, it is evident that in the conditions of increasing sales of electric vehicles, there is a positive trend in increasing semiconductor revenues globally, while at the same time, revenues in Europe are decreasing, indicating a shift in market conditions and companies' reorientation towards other regions. This analysis is supported by higher costs in Europe and the investments made over the past 5 years, which also have an impact by not allowing rapid price decreases and increasing competitiveness.

The focus on operational optimization and cost reduction in the automotive industry is rooted in cost management theory. According to this theory, effective cost management is crucial for achieving competitive advantage and maintaining profitability. To ensure sustainability and growth, companies are focused on improving operational efficiency by reducing unnecessary expenses and optimizing work processes.

Additionally, in line with market theory, the growth of the electric vehicle market in China can be explained by several factors, including the presence of stimulating government policies to promote electric vehicles and

increasing awareness of the need for environmentally sustainable transportation solutions.

Regarding the participation of European chip manufacturers in the Chinese market, this can be viewed from the perspective of the theory of international trade. According to it, countries specialize in the production of goods and services in which they have a comparative advantage, and trade is conducted with the aim of optimizing the use of resources and meeting the needs of the market.

3. Conclusion:

In the context of the global economy, the semiconductor market demonstrates significant growth, as evidenced by the increased revenues from 2019 to 2023. This trend is critically important given its central role and innovative applications in all sectors of the economy. This dependence finds strong reflection in the electric vehicle market where growth is observed due to the close relationship with the significant increase in semiconductor demand, as innovations in the automotive industry directly stimulate the development of the semiconductor industry. This synergy underscores the fundamental link between sustainable mobility and progress in electronic technologies, contributing to the dynamic development of both industries.

In addition to these findings, semiconductors integrated into the automotive industry represent 39.8% of the total market share, with electric vehicles occupying a dominant position within this segment at 83.3%.

Despite the noted global positive trends, the European market faces several challenges, including increasing imports from China. This aspect highlights potential risks and economic instability due to loss of competitiveness and leading positions in the field of innovation.

In the long term, forecasts for the global semiconductor market remain optimistic, predicting stable growth. However, a significant decrease in revenues in the European market is expected between 2024 and 2027 due to intensified competition and globalization of the world market.

4. Conclusions and results from the empirical study:

Product Portfolio Diversification: To maintain market share, European manufacturers should update their strategy to expand their product range by developing and implementing new products and services that meet current market expectations.

Increased Investment in Research and Development (R&D): A priority aspect is the need to increase investments in research and development in response to rapidly changing technological and market conditions and the importance of investing in technological competitiveness.

Improving Operational Efficiency and Cost Reduction: Stimulating innovation, improving technological competitiveness, and developing innovative solutions are key to optimizing operational efficiency and reducing production costs.

Establishment of Strategic Partnerships: In the context of globalization and consolidation of global players, it is recommended to build strategic partnerships with other organizations, including suppliers and research institutes. These alliances will form the basis for increasing innovation potential through the exchange of innovations, know-how, and research projects.

Focus on Sustainability and Green Energy: Given increasing social and public pressure, as well as strengthening regulatory frameworks towards environmental sustainability, it is essential for European manufacturers to integrate sustainable practices into the production process. This achieves non-price competitiveness in terms of quality, expressed both in enhancing corporate responsibility and as the most adequate response to societal requirements.

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