# Faculty of Business Economics

## Master of Management

***Master's thesis***

***A Chips industry in Europe: feasibility and viability in a global context***

**Thi Van Anh Quach**

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Strategy and Innovation Management

**SUPERVISOR :**

Prof. dr. Jean-Pierre SEGERS

2024
2025

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**STATUTORY DECLARATION**

I herewith formally declare that I have written the submitted Master's Thesis independently. I did not use any outside support except for the quoted literature and other sources mentioned at the end of this paper.

I clearly marked and separately listed all the literature and all other sources which I employed in producing this academic work, either literally or in content.

Hasselt, 04/06/2025

Signature

Quach Thi Van Anh

## ABSTRACT

The European semiconductor industry has gained attention and ambition from the government and industry sector recently. To achieve greater strategic autonomy and capture a larger share of the global economic market, this sector faces increasing geopolitical challenges, supply chain vulnerability, and intense global competition. This thesis investigates how Open Innovation Ecosystems can help Europe navigate geopolitical challenges and secure a strategically significant role in the global semiconductor market. Through qualitative interviews with experts from government consulting, industry, and academia, the research reveals key barriers to the Open Innovation implementation, such as regulatory fragmentation, limited production capacity, talent gaps and commercialization of research results through startups and SMEs. The research highlights the importance of Public – Industry - Academic collaboration, supportive policies, and how to capture emerging technologies, such as AI and quantum computing, to foster the semiconductor industry in Europe. The thesis proposes actionable recommendations for policymakers, industry leaders, and academic institutions to promote collaboration, attract talent, and support SMEs and startups. By incorporating geopolitical risk into the Open Innovation framework, this research contributes to existing literature and offers practical insights for building a resilient and innovative European semiconductor ecosystem.

**Keywords**: Open Innovation, Semiconductor, Geopolitical Challenges, Technology Sovereignty, Triple Helix Model, US CHIPs Act, EU CHIPs Act, Made in China, European semiconductor, semiconductor workforces.

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**LIST OF ABBREVIATIONS**

| | |
|---|---|
| OIEs | Open Innovation Ecosystems |
| AI | Artificial Intelligence |
| U.S | United States |
| EU | European Union |
| UK | United Kingdom |
| R & D | Research & Development |
| SIA | Semiconductor Industry Association |
| WSTS | World Semiconductor Trade Statistics |
| IC | Integrated Circuit |
| IoT | Internet of Things |
| IDM | Integrated Device Manufacturer |
| PPP | Public-Private Partnership |
| IMF | International Monetary Fund |
| FTA | Free Trade Agreement |
| FDI | Foreign Direct Investment |
| OEM | Original Equipment Manufacturer |
| SMEs | Small and Medium Enterprises |
| STEM | Science, Technology, Engineering, Mathematics |
| PISA | Program for International Student Assessment |
| CAGR | Compound Annual Growth Rate |
| MIC | Made in China |
| SOEs | State-Owned Enterprises |
| POEs | Private-Owned Enterprises |
| TSMC | Taiwan Semiconductor Manufacturing Company |

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# CHAPTER 1: INTRODUCTION

This chapter highlights the reason behind selecting the research topic, sets the research objectives, forms the main research question & following sub-questions, and provides the overall thesis structure.

## 1.1 Background and Motivation

As Chris Miller, the author of Chip War book, started with his speech at World Knowledge Forum late 2024 that, "Semiconductors today are at the core, not just of advances in technology, which are used to, but also at the center of global debate in economics and in international politics…cannot understand the world around without putting analysis of semiconductors at the center." Just a tiny chip, but it is the technology control behind the modern digital economy, powering all devices from consumer electronics like smartphones and computers to mobility like cars, aeroplanes…to advanced technology such as Artificial Intelligence (AI), and further quantum computing in the future. The geopolitical tensions and global competition are rising rapidly, especially when Trump comes back to lead the US with Trump's 2.0 government, with the reciprocal tariffs policy, control over making microchip technology, including the main parts from design, manufacturing, and supply chains, has become a critical strategy for nations worldwide.

Europe has world-class research institutions and a strong academic base, making it a hotspot research hub today (EuropeanCommission, 2025). However, the European semiconductor industry faces significant challenges securing its position in the global semiconductor landscape. Decades of outsourcing and a fragmented policy environment have made Europe dependent on foreign suppliers for the critical components, especially for production microchips, putting it at risk of a supply chain crisis.

This thesis addresses the urgent need to strengthen Europe's semiconductor industry by exploring the role of Open Innovation Ecosystems (OIEs hereafter) in helping Europe navigate the global tensions, fostering innovation, strengthening the chip economic ecosystem, and achieving strategic technology sovereignty.

## 1.2 Research objectives

This research aims to:

1) Analyse the current geopolitical challenges that impact Europe's semiconductor industry.
2) Study the best practices today about semiconductors, including the US and China and identify the gap between Europe and those markets.
3) Investigate the role of the OIEs in fostering innovation, collaboration, and increasing commercialization within the European semiconductor ecosystem.
4) Identify the key challenges and barriers to effectively applying the OIEs in Europe, including the geopolitical, regulatory, business and talent gap.
5) Develop actionable recommendations for policymakers, industry leaders and academic institutions to strengthen the semiconductor sector in Europe.

## 1.3 Research questions

This research focuses on the central question: "How can Open Innovation Ecosystems help Europe navigate geopolitical challenges and secure a strategically significant role in the global semiconductor market?"

From this core question, the research also seeks the answer to the following subtopics and questions:

1) Geopolitical and Strategic Dimensions
    a. How do current geopolitical challenges, at the global and regional levels, such as the US-China trade conflicts and conflicts between European members, impact Europe's semiconductor industry?
    b. What strategies can Europe adopt to reduce its dependency on external semiconductor suppliers?
2) Open Innovation Framework
    a. What are the key characteristics of successful OIEs in the semiconductor industry?
    b. How can the Triple Helix Model framework help Europe gain and sustain its strategic position in the chip sector?
3) Comparative Analysis and Best Practices
    a. What lessons can Europe learn from leading semiconductor ecosystems like those in the US and China? And what should the EU focus on in the emerging country in the Chips race, like Vietnam?
    b. How do different regions foster industry, academia, and government collaboration for chip innovation?
4) Policy and Investment
    a. How can European policies, including the EU Chips Act, better support OIEs?
    b. What funding and investment models are required to sustain a thriving European semiconductor innovation ecosystem?
5) Emerging technologies: AI & Quantum Computing
    a. How does the rise in AI and Quantum computing influence Europe's need for a stronger semiconductor industry?

## 1.4 Research contributions

This research contributes to the literature on the OIEs links with geopolitical risks in the high-tech industry, particularly in the semiconductor industry in Europe and Europe's semiconductor policy, industry collaboration and building workforce. In which:

1) Integrating geopolitical challenges as a key factor in analyzing the OIEs in making strategic policy for the European semiconductor sector.
2) Providing real-world insights from in-depth interviews with professional experts on the key challenges and opportunities for promoting the Open Innovation model in Europe.
3) Suggesting actionable recommendations for policymakers, industry leaders, and universities to strengthen the OIEs in Europe.

## 1.5 Thesis structure

This research is structured with six chapters, including:

1) Chapter 1: Introduction

This chapter presents the reason behind the research chosen and sets the goals for the research.

2) Chapter 2: Theoretical Background and Literature Review

In this chapter, I will provide an overview of global and within Europe semiconductor value chains, including the best practices in the global industry and emerging technologies links, highlight geopolitical challenges for Europe, and relevant literature on the OIEs.

3) Chapter 3: Research Methodology

This chapter outlines the research methodology, including qualitative research design, data collection methods, and data analysis.

4) Chapter 4: Findings

This chapter highlights the key findings of the in-depth interviews with government consultants, industry experts, and academic professors, who were carefully selected to provide real-world insights into the semiconductor industry.

5) Chapter 5: Research Conclusions and Contributions

This chapter discusses the key findings and outlines theoretical and practical contributions.

6) Chapter 6: Research Limitations and Future Prospects

This chapter identifies the limitations of the research and suggests promising directions for future research.

# CHAPTER 2: THEORETICAL BACKGROUND AND LITERATURE REVIEW

This chapter provides an overview of the semiconductor value chain globally, geopolitical challenges, zooming in on Europe, and analyses the US and China case studies, the impact of emerging technologies and markets on the European semiconductor industry. After that, carefully review the theoretical background of Open Innovation and other relevant literature to set the foundation for this research.

## 2.1 Introduction of Semiconductor Value Chains

### 2.1.1. The complexity of the semiconductor supply chain journey

The global semiconductor industry is based on a collaborative system of "mutual dependencies", which means no single region possesses end-to-end capabilities for semiconductor design and manufacturing (ASML, 2022). Microchips can go by many names: integrated circuits, semiconductor chips, computer chips, or, most simply, chips. In any case, these tiny pieces of silicon are the foundation of the digital world. They are used to make smartphones, cars, medical equipment, and so many other now-common devices possible – and the tinier they get, the more advanced technology in the everyday world. They may be small, but their impact is tremendous, according to the ASML definition. Therefore, making a tiny chip must go through four primary stages with over 1,000 steps. It makes the semiconductor supply chain one of the most complex and globally interconnected processes. This chain operates across multiple continents, from Europe and the Americas to Asia, with the final products distributed worldwide to meet the demands of various industries.

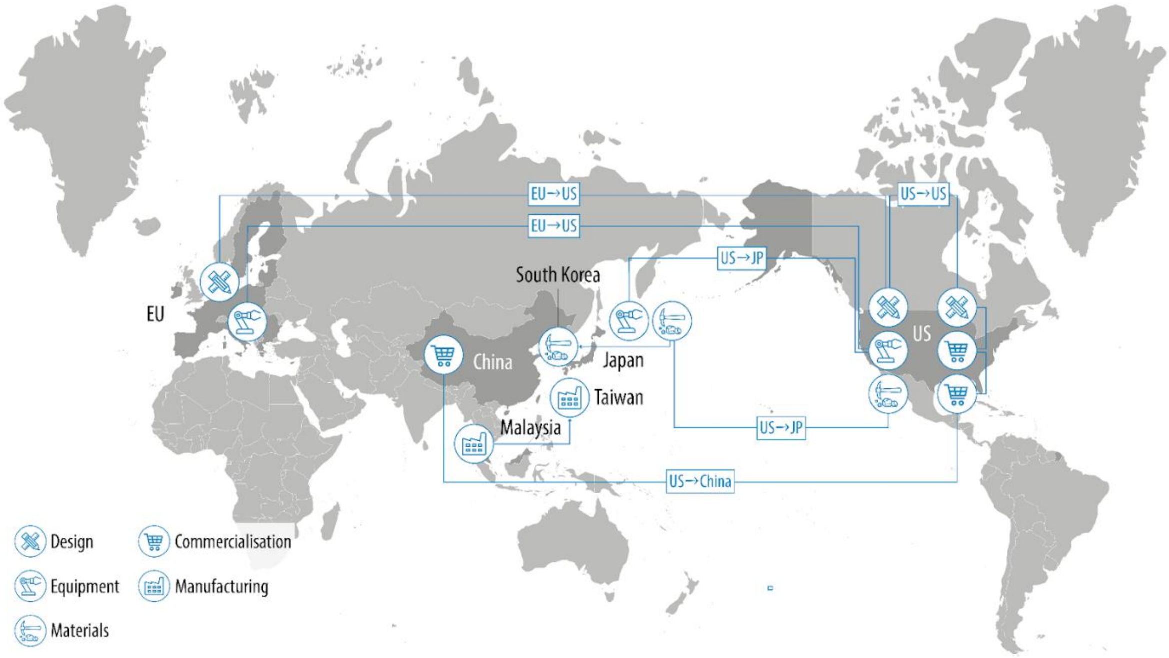


*Figure 2.1: Semiconductor supply chain map, European Parliamentary Research Service (adapted from Source: Semiconductor Industry Association, 2021)*

In the making of a chip, there are four stages that take place around the world to complete one chip.

**Stage 1: Research & Design**

The semiconductor supply chain begins with the research & design phase. During this stage, companies make significant investments in research and development (R&D) to create cutting-edge semiconductor technologies. This phase requires advanced microelectronics, materials science, and computer engineering expertise. This phase is mainly in Europe and the US, with well-known companies such as research center IMEC (Belgium, EU), Intel (the US), and NVIDIA (US).

**Stage 2: Manufacturing (Foundries)**

Once the design is finalized, the process moves to the manufacturing stage, which takes place in specialized facilities known as foundries or fabs. These large-scale production facilities are responsible for fabricating semiconductor wafers using highly sophisticated processes, such as photolithography and etching. While ASML (EU) is a one-of-a-kind company that provides a holistic lithography product portfolio (both equipment and software), leading global foundries, including Taiwan Semiconductor Manufacturing Company (TSMC), Samsung Electronics (South Korea), and GlobalFoundries (the US), dominate this stage due to their advanced technological capabilities and economies of scale.

**Stage 3: Assembly, Testing and Packaging (ATP)**

After manufacturing the wafers, they proceed to the assembly and test chips. During this stage, individual semiconductor chips are separated from the wafer and mounted onto substrates. The chips are then connected using fine wires or advanced flip-chip bonding techniques. Rigorous testing procedures are conducted to ensure each chip's functionality, performance, and reliability. This phase is critical for identifying and eliminating defects before the chips move further down the supply chain.

Following successful testing, the semiconductor chips enter the packaging phase. Packaging is essential for protecting the chips from environmental factors such as moisture, heat, and physical damage. It also facilitates the integration of chips into electronic devices by providing electrical connections and thermal management. Advanced packaging technologies, such as 3D packaging and system-in-package (Sip), are increasingly used to make a chip smaller but more powerful.

This stage is controlled mainly by companies in China and Taiwan, which shared 30% and 27%, respectively, in 2022 (Statista, 2022).

**Stage 4: Distribution and Integration**

The final stage of the semiconductor supply chain involves distribution and integration. Packaged semiconductor chips are shipped to original equipment manufacturers (OEMs) and electronics companies worldwide. These chips are then integrated into various products, including consumer electronics (e.g., smartphones, laptops…), industrial machinery, automotive systems, and medical devices. The global distribution network ensures that semiconductors reach end-users efficiently, supporting the functioning of modern technology-driven economies.

In this complex supply chain value, Europe only appears significantly in the first stage, considered a Fabless business model, and controls the lithography equipment for this industry, which is one of the essential parts of producing a chip. However, Europe lacks the capacity of the rest of the supply chain stages. These missing parts will lead to a smaller role, the ability to control technological sovereignty, and reduce the dependence on foreign technologies in the future if no action is addressed (Gilpin, 1987). It also gives the sense that if Europe wants to gain market share in the chip industry, it must expand to other business models to strengthen its chip production capacity.

### 2.1.2 Turning point of the semiconductor sales market

In the global semiconductor industry history, from 1986, the four main regions worldwide shared similar sales value sizes and had the same growth trend till 2000. There was the US contributed 31%, Europe 21%, Japan 23%, and the Asia Pacific 25% in 2000. However, starting from 2001, the market trend was in two different ways and split the semiconductor market into two extreme directions (see Figure 2.2). While Asia Pacific, which includes China, South Korea, Taiwan & others, grew significantly and took a half of the market with 53% in 2024, the US still stayed in the same contribution with 31% as they got in 24 years ago; Europe and Japan dropped dramatically to just 8% and 7%, respectively.

Last year, 2024, with the booming AI revolution and peak demand for semiconductors, marked the new race for this industry; the global semiconductor sales achieved $627.6 billion, which increased by 19.1% compared to the 2023 total of $526.8 billion (SIA, 2025). This is the first time the semiconductor market has reached over $600 billion. However, the performance showed different results in different regions and countries. In 2024, yearly sales in the US were up 44.8%, while China grew 18.3% and Asia Pacific was 12.5%. Sales were down in Japan by -0.4% and somewhat down in Europe at -8.1%. These sales not only illustrate Europe's sales going in the opposite direction compared to the US and Asia but also signal that Europe needs to look for an urgent solution to secure the market and Europe's position in the semiconductor industry in the future.

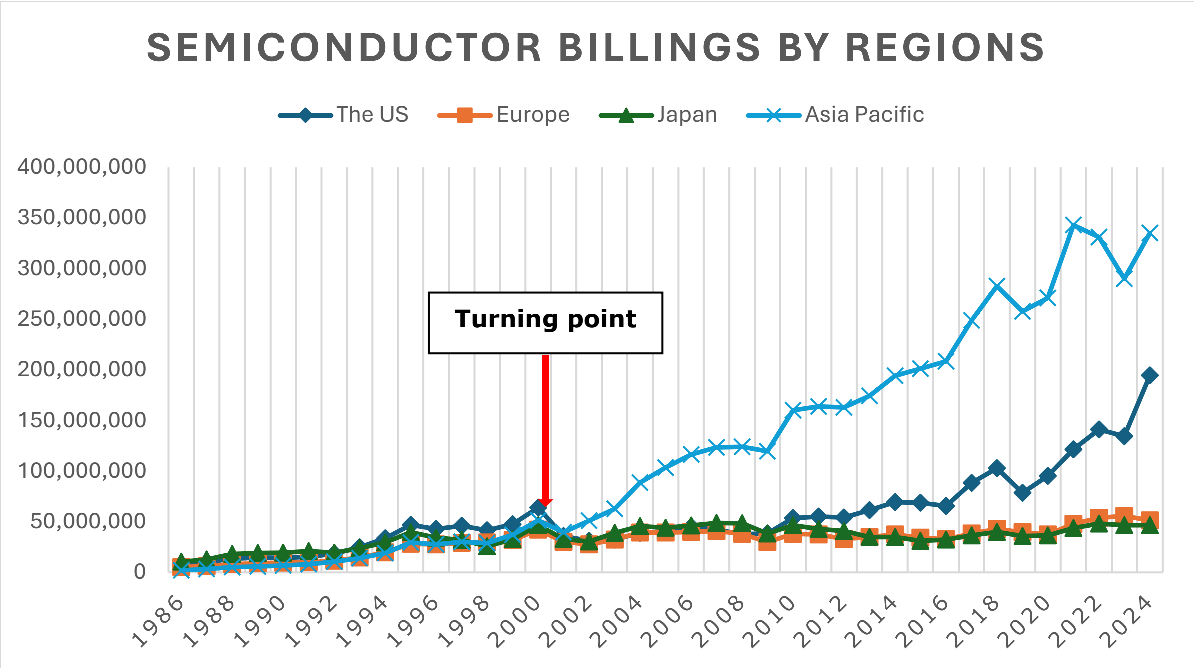


*Figure 2.2: Semiconductor sales value by year from 1986 to 2024, data from World Semiconductor Trade Statistic www.wsts.org*

### 2.1.3 Overview of international semiconductor companies

The overview of companies in the semiconductor industry nowadays is so dynamic, with 470 listed companies in various stages, 188 companies in Testing engineering, 150 companies in Design, 101 in Packaging, and 31 companies in Foundries, according to a Statista survey in 2021 (Statista, 2021). In terms of market value, 130 companies with a market cap higher than $100 million. The table below shows the top companies in each category. There is one highlight that in the fabless field, giant tech companies such as Meta, Apple, Google, Amazon, and Tesla are also starting to enter the field of research and design chips and compete with the traditional fabless chip firms. It makes this industry more competitive than ever.

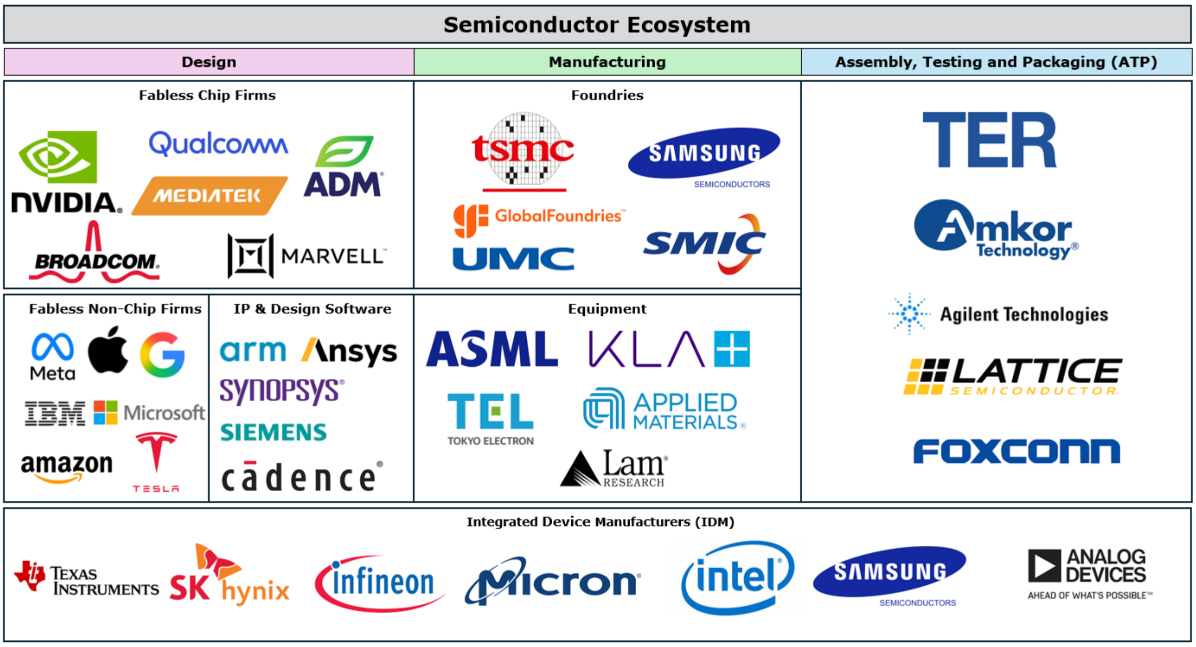


*Figure 2.3: Companies in Semiconductor Ecosystem, collected & updated in* May *2025*

Technological change is accelerating rapidly. Europe largely missed out on the digital revolution led by the internet and the productivity gains it brought. In fact, the productivity gap between the EU and the US is largely explained by the tech sector. The EU is weak in the emerging technologies that will drive future growth (Draghi, 2024). In the top 20 largest semiconductor companies by market cap in February 2025 (see the figure 4 below), Europe has only two companies: ASML in the Netherlands and Arm Holdings in the UK; the US dominates with 13 of 20, Taiwan has 2, South Korea has 2, and Japan has 1. Another key point is that the market value cap of ASML ($295.5 billion) is medium-sized, only accounting for one-third of Taiwan's TSMC ($1.057 billion) and less than 10% of NVIDIA ($3,400 billion), which is the market leader. This shows that Europe has fewer companies in the semiconductor industry than the US and Asia, and they do not reach the size to compete strongly in the market, such as the leaders of US or Taiwanese companies.

| Rank | | Name | Market Cap | Price | Today | Price (30 days) | Country |
|---|---|---|---|---|---|---|---|
| | 1 | NVIDIA NVDA | $3.400 T | $138.85 | ▲ 2.63% | | USA |
| | 2 | Broadcom AVGO | $1.092 T | $233.04 | ▼ 1.17% | | USA |
| | 3 | TSMC TSM | $1.057 T | $203.90 | ▲ 1.03% | | Taiwan |
| | 4 | ASML ASML | $295.50 B | $751.55 | ▼ 3.27% | | Netherlands |
| | 5 | Samsung 005930.KS | $256.06 B | $38.67 | ▲ 0.36% | | S. Korea |
| | 6 | QUALCOMM QCOM | $190.48 B | $172.23 | ▲ 0.05% | | USA |
| | 7 | AMD AMD | $183.27 B | $113.10 | ▲ 1.15% | | USA |
| ▲1 | 8 | Arm Holdings ARM | $168.15 B | $159.54 | ▼ 3.21% | | UK |
| ▼1 | 9 | Texas Instruments TXN | $166.96 B | $183.03 | ▲ 1.23% | | USA |
| | 10 | Applied Materials AMAT | $137.50 B | $169.20 | ▼ 8.18% | | USA |
| ▲2 | 11 | Micron Technology MU | $110.88 B | $99.52 | ▲ 4.04% | | USA |
| ▲2 | 12 | Analog Devices ADI | $106.47 B | $214.61 | ▲ 2.52% | | USA |
| ▼1 | 13 | Lam Research LRCX | $106.22 B | $82.75 | ▼ 0.66% | | USA |
| ▼3 | 14 | Intel INTC | $102.18 B | $23.60 | ▼ 2.20% | | USA |
| ▲1 | 15 | SK Hynix 000660.KS | $99.96 B | $145.01 | ▲ 0.72% | | S. Korea |
| ▼1 | 16 | KLA KLAC | $99.76 B | $750.74 | ▼ 1.77% | | USA |
| | 17 | Marvell Technology Group MRVL | $92.16 B | $106.51 | ▲ 2.91% | | USA |
| | 18 | Synopsys SNPS | $80.77 B | $522.53 | ▼ 1.09% | | USA |
| | 19 | Tokyo Electron 8035.T | $73.93 B | $161.40 | ▼ 2.07% | | Japan |
| | 20 | MediaTek 2454.TW | $73.14 B | $45.89 | ▼ 0.99% | | Taiwan |

*Figure 2.4: The Top 20 largest semiconductor companies by market cap* (screenshotted *from* *www.companiesmarketcap.com on 16th February 2025).*

The microelectronics value chain is contributed by a few main countries and regions. According to Strategy&, a part of the PwC network, report 2023 (Strategy&, 2023), while Europe controls tools and equipment, with the monopoly player being ASML, the US leads most of the Design and Algorithms parts, the Front-end, Back-end, and Assembly parts are managed by Asia countries, such as Taiwan, China, South Korea and Japan, and Materials/Wafer is shared by all these regions (see more information in Figure 2.5).

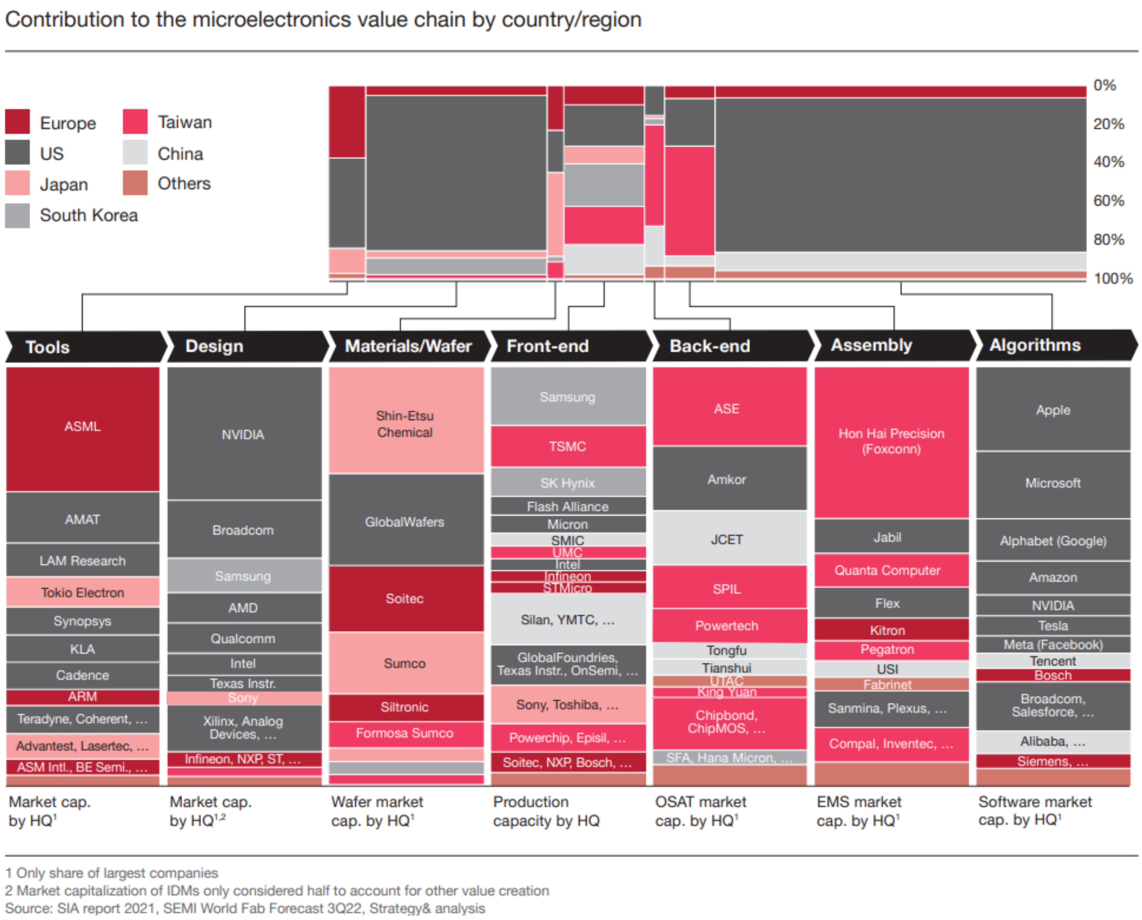


*Figure 2.5: Contribution to the microelectronic value chain by country/region,* screenshotted *from Strategy& report, 2023.*

## 2.2 Semiconductor Geopolitical Situation

### 2.2.1 An Overview of Semiconductor Geopolitical Characteristics

Semiconductors are the building blocks of modern technology, essential for everything from smartphones and computers to cars and military systems. The supply chain is global and complex. Therefore, owning semiconductor technology at any stage in this value chain is critical and becomes a new power, especially when AI surges. Semiconductors are now considered a geopolitical economy for a country to use not only to push a growth economy but also for the country's security to face geopolitical tensions. It is a structural power with the impact of setting trade policies, controlling financial systems, and economic nationalism, leading the government to prioritize national interest over global competition (Strange, 2015).

The semiconductor trade space is highly unbalanced, with materials and equipment trade highly concentrated in a few countries on both the supply and demand sides. China has replaced the US as the largest global semiconductor trade player and has shaped the regionalized system of manufactured goods and materials trade with East and Southeast Asian economies, but its equipment trade is highly dependent on Europe and the US. The semiconductor production model has promoted the regionalization of the East and Southeast Asia region in the trade of manufactured products and materials, and developed economies such as the US, the EU, Japan, and South Korea have maintained their monopolistic advantage in the trade of semiconductor equipment by building exclusive innovation networks and establishing trade barriers (Ren et al., 2023).

The US is leading the market in various segments, from R&D to foundry, and owns 38% of the total value chain, sharing 25% in total consumption; Europe has 10% of the total value chain but shares 20% of total consumption, and China shares only 9% in total value chain but consumed 24% (see Figure 2.6).

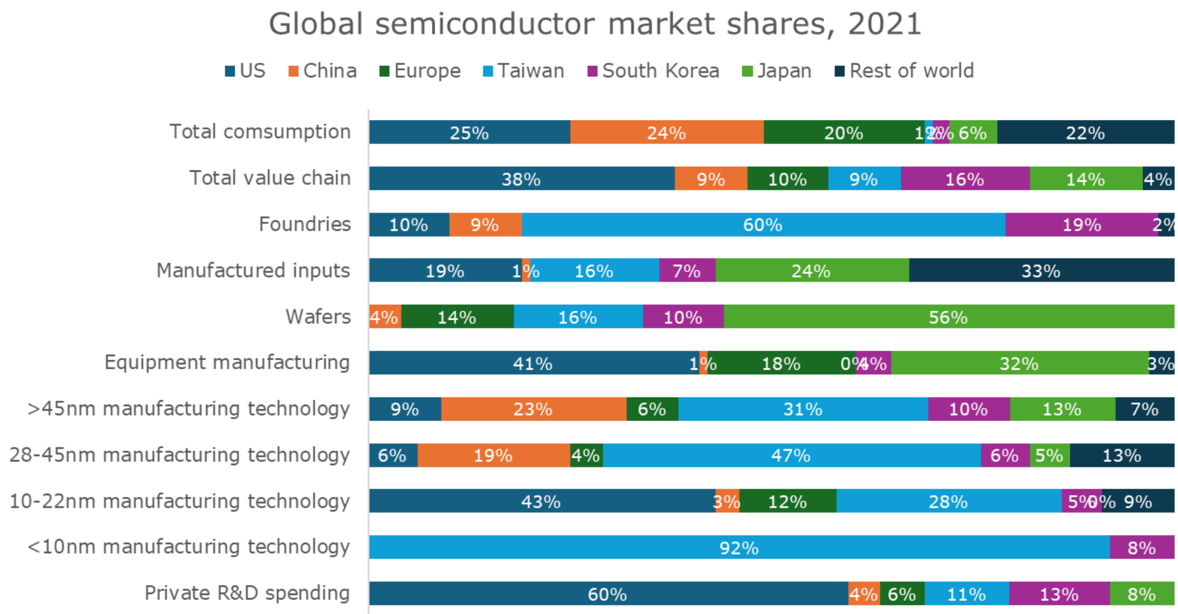


*Figure 2.6:Global semiconductor market shares, 2021*, data source Center for Security and Technology and Semiconductor Industry Association (SIA*)*

### 2.2.2 The US-China tensions and impact on chip supply chains

Just one month after Trump became the 47th President of the United States, he made a critical inflection point for the trade war between the US and China, with semiconductor manufacturing and innovation serving as the center battlefield. This transformed the trade war before into a tech war now. Overall, the US reached $195 billion and shared 31%, according to World Semiconductor Trade Statistics (WSTS, 2024) of the semiconductor market in 2024, which grew 45% from 2023, while China achieved approximately $116 billion. It contributed 18% of the global market and grew 18.3% by 2023. The US is reducing its contribution while China is gaining market share yearly. The US and China also want to take the lead in controlling the semiconductors and using them as a key power weapon in this tech war. However, this industry is too complex to be owned by one company or country. Since 2015, China has launched the Made in China 2025 strategic plan; the US and China have used policy to battle closely on each new move (see Table 1). Within 10 years, the US government made 14 major decisions, mainly to restrict China's access to the US's semiconductor technology and restrain China's speed in semiconductor sovereignty.

### 2.2.3 Summary of the US-China Semiconductor Conflict Events (2015–2025)

Here is the overview table of the US-China conflict events within a ten-year period, from 2015 to 2025, under the Donald Trump presidency, the Biden presidency of the US and Xi Jinping, general secretary of the Chinese Communist Party. Each country has had movements and reactive policies to restrain or prevent the remaining country, particularly focusing on the Semiconductor sector.

| Time | China moves | The US moves |
|---|---|---|
| September 2015 | Launched the "Made in China 2025" plan, aiming to become self-sufficient in key technologies, including semiconductors. | |
| April 2018 | | Imposed export controls on ZTE (a Chinese 5G telecom technology company), restricting access to American technology due to sanctions violations. |
| October 2018 | | Banned Chinese chipmaker Fujian Jinhua from purchasing US semiconductor technology over intellectual property theft concerns. |
| May 2019 | | Placed Huawei on its "Entity List" and blocked US firms from supplying semiconductors and software without special approval. |
| July 2019 | | Persuaded the Netherlands to restrict ASML from selling advanced extreme ultraviolet (EUV) lithography machines to China. |
| September 2020 | | Further tightened restrictions on Huawei, limiting its access to chips made with US technology, even from overseas manufacturers like TSMC. |
| December 2020 | | Put China's largest chipmaker, SMIC, citing military ties, on the blacklist, restricted its ability to obtain US semiconductor technology. |
| March 2021 | | The US and its allies, including Japan, the Netherlands, and South Korea, discussed forming a semiconductor alliance to reduce dependency on China. |
| July 2021 | China accelerated investment in domestic chipmaking to counter U.S. restrictions, including massive funding for SMIC and new semiconductor startups. | |
| August 2022 | | The US enacted the "CHIPS and Science Act," allocating $52.7 billion to boost domestic |

| | | |
|---|---|---|
| | | semiconductor manufacturing and reduce reliance on China. |
| October 2022 | | The U.S. implemented sweeping export controls to block China from acquiring advanced semiconductor technology, including AI chips from NVIDIA and AMD. |
| June 2023 | | Under pressure from the US, the Netherlands officially banned ASML from exporting deep ultraviolet (DUV) lithography equipment to China. |
| October 2023 | | The Biden administration tightened export controls, closing loopholes that allowed China to access advanced AI and semiconductor technologies. |
| January 2024 | China retaliated by restricting exports of key semiconductor materials like gallium and germanium, essential for advanced chip production. | |
| June 2024 | | The US and EU announced a strategic semiconductor partnership to strengthen supply chain security and counter China's dominance in certain materials. |
| January 2025 | | The US announced a 100% increase in tariffs on Chinese semiconductor imports. This move aims to protect the $52.7 billion investment made under the CHIPS Act to bolster domestic chip production. |
| January 2025 | | Biden's last-day issued new restrictions on exporting U.S.-developed AI chips to countries like China and Russia, aiming to prevent adversaries from accessing advanced AI technologies from China or Russia and third countries, especially from the Middle East. |
| February 2025 | Imposes a 10-15% tariff on US coal, LNG, and agricultural machinery in retaliation for the US tariffs. | Trump imposes a 10% tariff on all Chinese product imports, including semiconductors, and a 25% tariff on steel and aluminium. |

| | | |
|---|---|---|
| April 2, 2025 | Announces a 34% tariff on all US products, matching Trump's new reciprocal tariff; imposes export controls on rare earth minerals. | Trump imposes a 34% reciprocal tariff on most Chinese imports, including semiconductors. |
| April 9, 2025 | Raises tariffs on US imports to 84% in response to the US. | Trump raises tariffs on Chinese imports by an additional 50%, bringing the baseline tariff to 104%. |
| April 11-12, 2025 | Raises tariffs on US goods to 125%, matching the new US rate; announces it will no longer respond to further US tariff hikes. | Trump again raises tariffs to 145% on Chinese imports; warns that exemptions (such as for semiconductors) may not be permanent. |
| May 9-12, 2025 | Participates in Geneva, Sweetland talks, agrees to temporarily reduce tariffs as part of a 90-day truce. | The US and China agree to temporarily slash reciprocal tariffs for 90 days to ease global trade tensions, back to 10%, plus the existing 20%, making a total of 30% on Chinese goods. |

*Table 1: Collect and consolidate from different sources: U.S Department of Commerce, U.S Department of Justice, U.S Department of Defense, U.S. Bureau of Industry and Security (BIS), State Council of the People's Republic of China, China Ministry of Commerce, China-briefing.com Europe Commission, ASML, NVIDIA, Reuters, Financial Times, Bloomberg, CNN, Newsweek.*

Although the US has tried to prevent and control China in this sector, China shows that it has significantly improved technology autonomy. Diving deeper into the semiconductor market, the controllability of each country in a specific semiconductor is different.

Regarding technology development, the US is still a leader in the Design and R&D stage and is the largest manufacturer of advanced chips through TSMC's Arizona fab (3nm production) and Intel's Ohio complex (18A node equivalent to 1.8nm). The US also controls advanced chips smaller than 10nm. However, regarding advanced processes, Huawei's Mate60, launched in 2023, was confirmed to utilize 7 nm process technology, marking a significant breakthrough in Chinese-produced high-end chips. Regarding mature processes, data from international consulting firm Knometa Research showed that by 2022, there were 167 12-inch wafer fabs worldwide, with 13 new fabs coming online in 2023, bringing the total to 180. In terms of quantity, nearly half of the world's 12-inch wafer fabs are located in China. Due to its complete industrial chain, robust production capacity, and cost advantages, China has a clear comparative advantage in producing mature-process chips (Eurasiareview, 2025). In memory chips, China's Yangtze Memory Technologies Corporation (YMTC) now produces 232-layer 3D NAND, matching Micron and SK Hynix (from South Korea) capabilities, the highest-performance technology in this area (Reuters, 2022).

### 2.2.4 China, with the Made in China 2025 strategy

In 2015, the Chinese government, inspired by the concept of Germany's Industry 4.0 program, launched the Made in China 2025 (MIC 2025) program, transforming its manufacturing sector from low-cost production to smart manufacturing and becoming a global leader in advanced technology. The plan targeted three key goals: 1) Achieve 40% domestic content in core materials by 2020 and 70% by 2025; 2) Reduce reliance on foreign technology in sectors like semiconductors, AI, and robotics; 3) position China as a global innovation hub in advanced manufacturing. With this plan, China aims to lock out foreign firms and monopolize global markets. (Morrison, 2014). It raises significant challenges for the rest of the industrialized world, especially the US and Europe, because eventually, companies that have already set shop in China lose business to the Chinese companies because of the 'self-reliance' and 'technological competitiveness' developed by them as a result of the incentives provided by MIC25. (Agarwala & Chaudhary, 2021).

Up to 2024, China is the single largest export market for semiconductors globally, accounting for 29% of global chip sales in 2023. Especially from the production standpoint, China accounts for roughly 20% of front-end and nearly 40% of back-end semiconductor manufacturing capacity, according to SIA (SIA, 2024). China achieved impressive results from this plan, posing a significant threat to the rest of the world regarding technology development, gaining market share, and increasing the dependence on manufacturing and supply chains from China; even the US and others, such as Europe, have tried to prevent or restrain China.

**China-state-driven innovation approach**

While the US is the most open market and has deep interaction among three parties: government, firms, and universities, China is led by the state's will. In 2015, when the Chinese government changed its strategy from a low-cost manufacturing model to smart manufacturing, it reshaped China's economy through the strategic plan MIC 2025, as we can see today.

MIC 2025 targeted 70% self-sufficiency in semiconductors by 2025 through $300 billion in state-led investments. Key mechanisms included:

- Tax Incentives: Reduced corporate tax rates for qualified semiconductor firms from 25% to 15%.
- R&D Funding: Direct state allocations for advanced packaging and materials science, with $150 billion earmarked in the 2014 National IC Strategy.
- Domestic Procurement Mandates: Requirements for industries like electric vehicles to source 40% of automotive chips locally by 2023.

China has pursued policies aiming to build a globally competitive domestic industry. As a socialist market economy, the Chinese government has often taken an active role in the innovation process, driving a considerable portion of R&D and domestic firm innovations (Guan & Yam, 2015). To promote knowledge transfer and improve intellectual property management, the government has established an open knowledge-sharing system for national research institutions. This was made possible by the 2015 revision of the Law for Promoting Commercialization of Science and Technology Results, which granted universities and scientists greater control over technology transfer (ESCAP, 2018). Policy instruments include outlays on technical education and more focused initiatives that channel investment funds, imported technology, and product demand toward domestic firms, primarily state-owned ones. (Fuller, 2019). China has built The Belt and Road Initiative, which can be seen as a country-level policy of Inside-Out pen innovation and the government as an orchestrator of open innovation and developing dynamic capabilities. (Chesbrough et al., 2021). Semiconductor can be seen as an implementation of The Belt and Road strategy. In the research of Chesbrough et al., 2021, he and his team applied Open Innovation and Dynamic capabilities to study China's Semiconductor and High-speed rail. They found that Open Innovation in Semiconductor was weak due to a lack of autonomy in State-Owned Enterprises (SOEs) and Preferential policies from the government for SOEs. The study also showed that the dynamic of Private-Owned Enterprises (POEs) in research and design chips has less investment and control from the state.

| **China** | **Semiconductor** | **High-speed rail** |
|---|---|---|
| Industrial characteristics | Heterogeneous, global, relatively shorter product life cycle | Heterogeneous |
| Key players | SOEs and POCs | Mainly giant SOEs such as CRRC |
| Dynamic capabilities | Sensing:<br>- Heavily invested in developing cutting-edge technologies<br>Seizing:<br>- Provided capital investment, tax schemes, and other incentive programs | Sensing, seizing, transforming:<br>- Sensed technological opportunities<br>- Leveraged the capabilities of domestic companies<br>- Continuously renewed policies to changing markets |
| Open Innovation | Weak<br>- Preferential policies for SOEs<br>- Lack of autonomy in SOEs | Strong<br>- Opened its domestic high-speed train market<br>- One Belt One Road Initiative<br>- Inside-out open innovation |
| Results | - Ineffective | - Effective |

*Table 2: Open Innovation in high-tech sector in China study, adapted from the study of Chesbrough et al., 2021*

However, on February 17, 2025, Chinese President Xi Jinping set off a frisson of economic excitement by speaking at a high-level symposium of private sector entrepreneurs. This is a rare and abnormal activity, and it gives much meaning to the private sector in China. The first activity of its kind since 2018, it was attended by some of the leading lights of China's technology and emerging sectors, with notable names including Huawei’s Ren Zhengfei, BYD’s Wang Chuanfu, Will Semiconductor’s Yu Renrong, Unitree Robotics’ Wang Xingxing, and Xiaomi’s Lei Jun. The meeting was organized to meet China's most important and significant tech enterprises, such as Jack Ma of Alibaba, founder Yu Renrong of Leng Youbin and Will Semiconductor…and the hottest new firm like Deepseek’s founder, Liang Wenfeng. Official estimates show that the private sector in China, which competes with state-owned companies, contributes more than half of tax revenue, more than 60% of economic output, and 70% of tech innovation. The meeting happened because global tensions have increased recently, and the US is aggressively using tariffs to put more pressure on China's economy, especially for restricting technology exports and restraining China from accessing advanced technology. Suppose the Chinese government can address the challenges with less strict policy, less control of POEs, openness to access to the state’s investment, and practical support of regulations. In that case, the Open Innovation of semiconductors in China will increase, promising extreme growth in China's technology capacity.

#### 2.2.5 The US with CHIPS & Sciences Act 2022

Looking back on the history of the US trade war with China, the US has started to use policy to prevent or restrain China in many ways. The CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act of 2022 was signed into law by former President Joe Biden on August 9th, 2022. The law received Congress's approval and strong support from the research and business communities. The CHIPS and Science Act (hereafter the Act) directs $280 billion in spending over the next decade. Approximately $52.7 billion was allocated to support semiconductor research, manufacturing, and workforce development, and another $24 billion worth of tax credits for chip production. In addition, about $200 billion is spent on specific investments in scientific R&D and commercialization. There is $3 billion for leading-edge technology and wireless supply chain programs (McKinsey, 2022). The Act shows that the US pursues the weaponization of global value chains as a new tool of techno-nationalism (Luo & Van Assche, 2023).

The US set 3 tiers to apply restrictions in export semiconductors, with China in tier 3, the most restrictive, and most countries in tier 2 (restrictive and watching out to add more potential risk countries to tier 3), and only some countries in the EU and Australia are in tier 1 with a strong relationship.

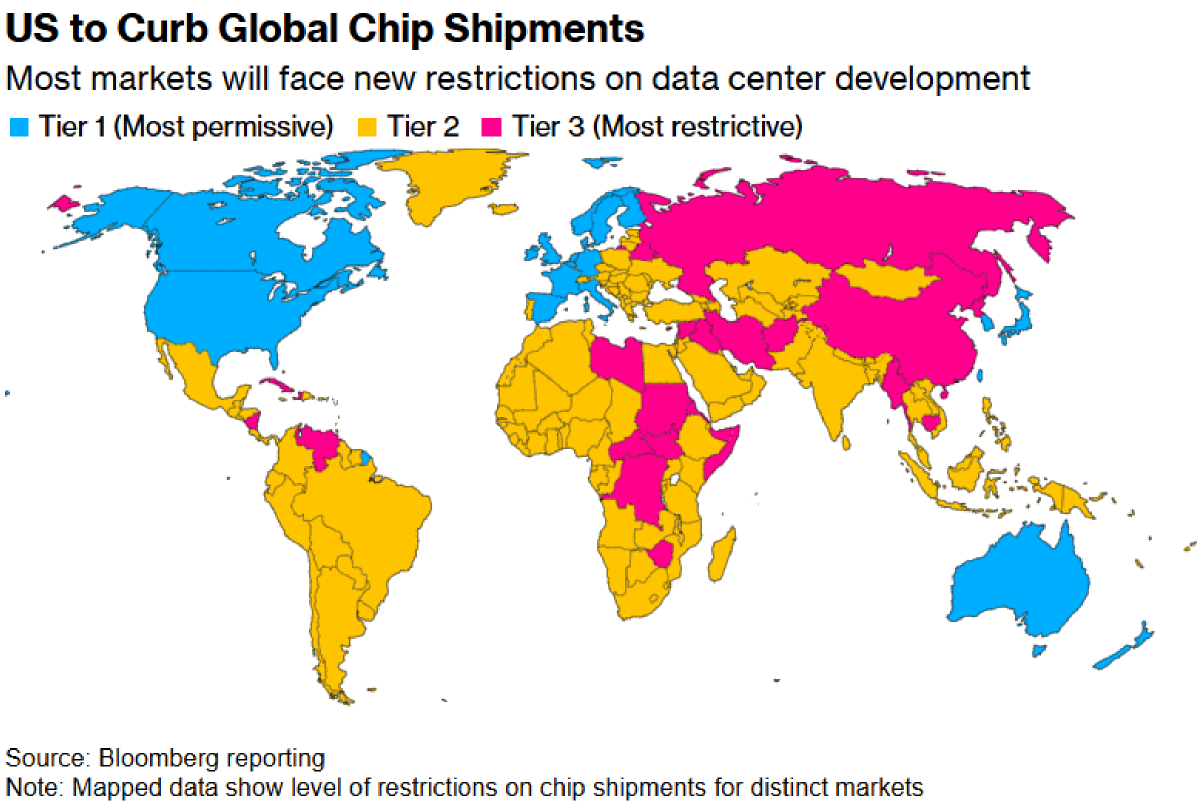


*Figure 2.7: US to Curb Global Chip Shipments (screenshotted from Bloomberg reporting, 2024)*

**The US with Silicon Valley – a comprehensive complex state-industry-academia approach**

The US has strengthened its semiconductor industry by leveraging a strong industry-academia collaboration model, particularly in Silicon Valley, the heart of the US's semiconductor center. This strategy, involving coordinated academic research, corporate innovation, and government funding, tackles supply chain issues, technological leadership, and workforce needs. The US's initiative CHIPS Act 2022, R&D hubs, and talent development programs have boosted domestic chip manufacturing capacity and innovation. Key achievements include the establishment of the National Semiconductor Technology Center (NSTC) in Sunnyvale, California, as the location for the second of three CHIPS for the US R&D flagship facilities, based in part on the depth of semiconductor expertise across the University of California and Silicon Valley's standing as a hotbed of chip design and innovation. The foundation of Silicon Valley's semiconductor dominance lies in the strong collaboration between academia and industry, starting in the 1960s. Fairchild Semiconductor and Intel's innovations in integrated circuits and Moore's Law propelled the industry forward. Stanford and UC Berkeley played vital roles, with Berkeley's prototyping lab creating a critical feedback loop where industry challenges drove academic research, and university advancements fueled commercial applications. Since UC Berkeley's pioneering integrated circuit prototyping lab in the 1960s, the University of California has been a global leader in chip technology (UniversityofCalifornia, 2024). Its technology transfer program has been instrumental in translating lab innovations into real-world applications, with UC faculty and alumni leading companies that developed essential modern technologies.

Today, the US has the world's most dynamic semiconductor business ecosystem. According to SIA, semiconductors became the sixth largest export sector in the US economy in 2023, with $52.7 billion, contributing 0.6% of total GDP, adding 2 million new direct and indirect jobs by 2030 to the labour market. The number of most prominent companies in the US is dominant in the list (6 out of the top 10), with NVIDIA being the largest company in all industries, with a valuation of more than $3,400 billion, equal to the rest of the nine companies in the list (see Figure 2.4). The US retained leadership in chip design and semiconductor equipment, with the names of a few, including NVIDIA, Intel, Applied Materials, LAM Research, KLA, Qualcomm, and AMD.

Along with the CHIPS Act 2022, R&D highest expenses among leader semiconductor countries, 19.5% in 2024, a strong network of research centers, an enterprise system led by Silicon Valley, and an America-oriented Trump government to support an ambitious semiconductor capacity goal in the next 10 years, aiming that it will increase from 11% in 2012-2022 to 203% in 2022-2032, being the highest growth capacity country in this industry.

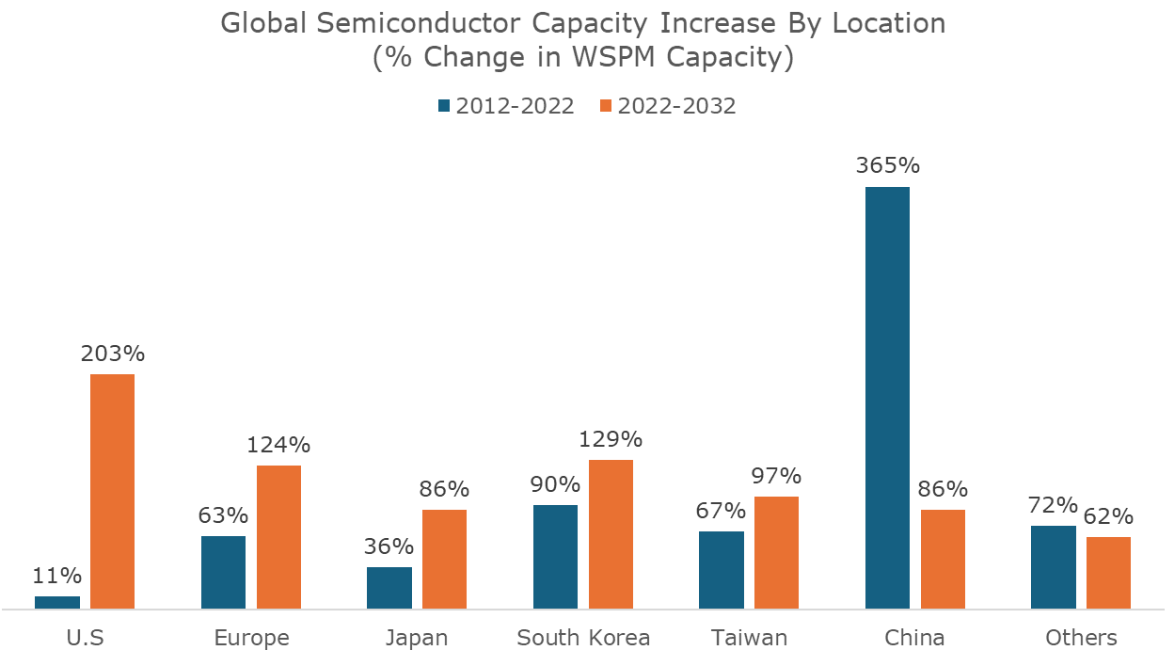


*Figure 2.8: Projection of global semiconductor capacity increase by location, adapted from SIA report, 2024*

## 2.3 Europe in the unleveled playing field

### 2.3.1 Europe's strategic position in the global landscape

Europe is in the middle between the United States and Asia, with time zones that average six hours later than Asia and six hours earlier than the Americas. Europe is also in the middle of the global map regarding population and economic size. This position poses a dilemma for Europe regarding collaborating and facing rising geopolitical challenges. With over 700 million people, there is substantial demand for connected devices and Internet of Things (IoT) technologies, the foundation for semiconductor demand. Regarding economic performance, Europe's GDP ($28.22 trillion, FY 2024) is comparable to that of the US ($30.34 trillion) and the combined economies of China, South

Korea, Japan, and Taiwan ($26.66 trillion) (IMF, 2025). Europe's GDP size is close to that of the US and Asia (a combination of key semiconductor countries China, South Korea, Japan, and Taiwan); however, Europe's economic growth trend has remained stable while the Americas and Asia keep the momentum of growth (see detailed in Figure 9). This may lead Europe to a growth race worldwide and cause it to be concerned about staying competitive in the evolving global semiconductor market.

Regarding Europe's Innovation and Economic Integration Index, it is higher than Taiwan and on bar status to China, but left behind the US and Japan, which may lead to the practical cooperation between Innovation fields and the Business sector - a critical factor in developing a strong semiconductor ecosystem. With the contribution of semiconductors in the economy being the lowest, just 0.2% among other key players, Europe's semiconductors will have a small role in the total business picture if they continue to obtain the current performance. In Taiwan and South Korea, semiconductors have become a significant position and are more and more critical they are contributing 20.1% and 7.3%, respectively. This will lead these governments to focus more on protecting their sales and markets. This creates more challenges for countries like Europe, the US, and Japan to take over the market share in the future (see Figure 2.9).

| **Country/ Region** | **GDP (current prices)**<br>*Billions of US Dollars*<br>*(FY 2024)* | **Semiconductor sales value (contribution to GDP)**<br>*Billions of US dollars (%)*<br>*(FY 2024)* | **Population**<br>*Millions of people*<br>*(FY 2024)* | **Innovation and Economic Integration**<br>*Index (FY, 2023)* |
|---|---|---|---|---|
| The US | 30.340 | 195.56 (0.6%) | 338.29 | 0.18 |
| ***Europe*** | ***28.220*** | ***51.26 (0.2%)*** | ***737.47*** | ***0.15*** |
| China | 19.530 | 90.99 (0.5%) | 1,411 | 0.15 |
| Japan | 4.390 | 46.55 (1.1%) | 123.26 | 0.18 |
| South Korea | 1.950 | 141.9 (7.3%) | 51.68 | 0.18 |
| Taiwan | 814 | 163.9 (20.1%) | 23.32 | 0.13 |

*Figure 2.9: Key data, source www.imf.org/external/datamapper/ , updated from the website to 14th February 2025*

Regarding R&D expenditure, the US is the leader, having invested 19.5% of its semiconductor revenue in 2023, while the EU is in second place with 14%. China used 7.6% of its revenue in R&D (see Figure 2.10 and 2.11). The EU is increasing spending under the Chips Act 2023 launch initiative and is committed to pushing semiconductors to the center of research and innovation. This investment can lead to a return on the investment for the EU in the next few years to reach the goal of its Chips Act 20% market share by 2030.

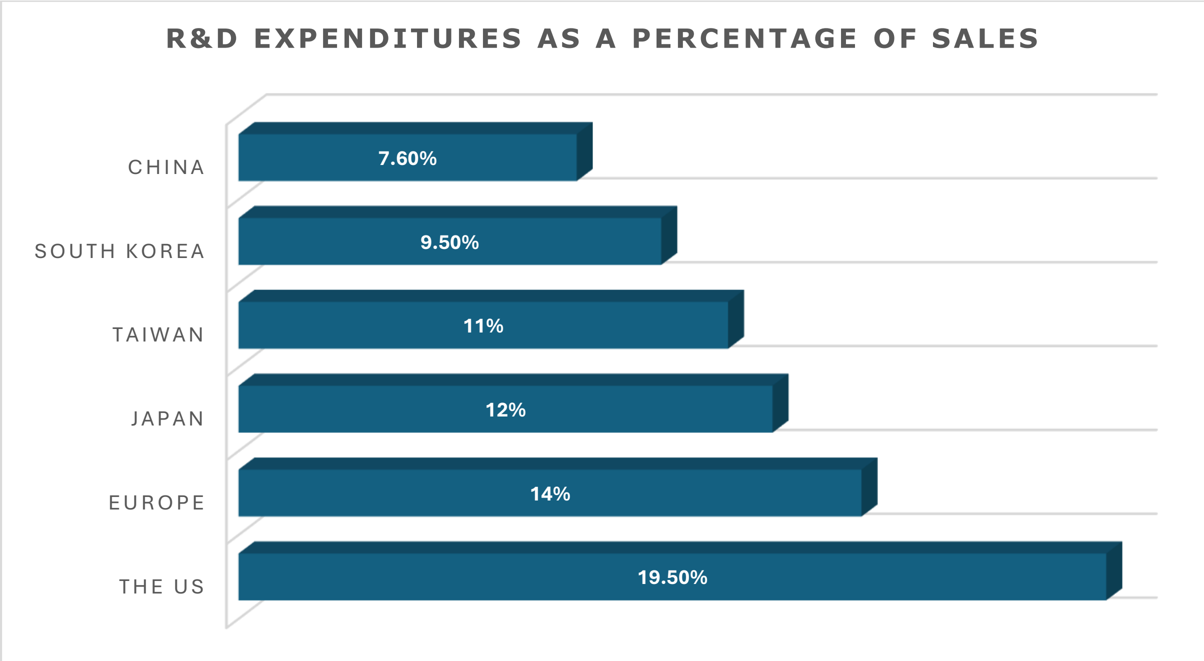


*Figure 2.10: R&D Expenditures by country/region. Adapted from SIA report, 2024*

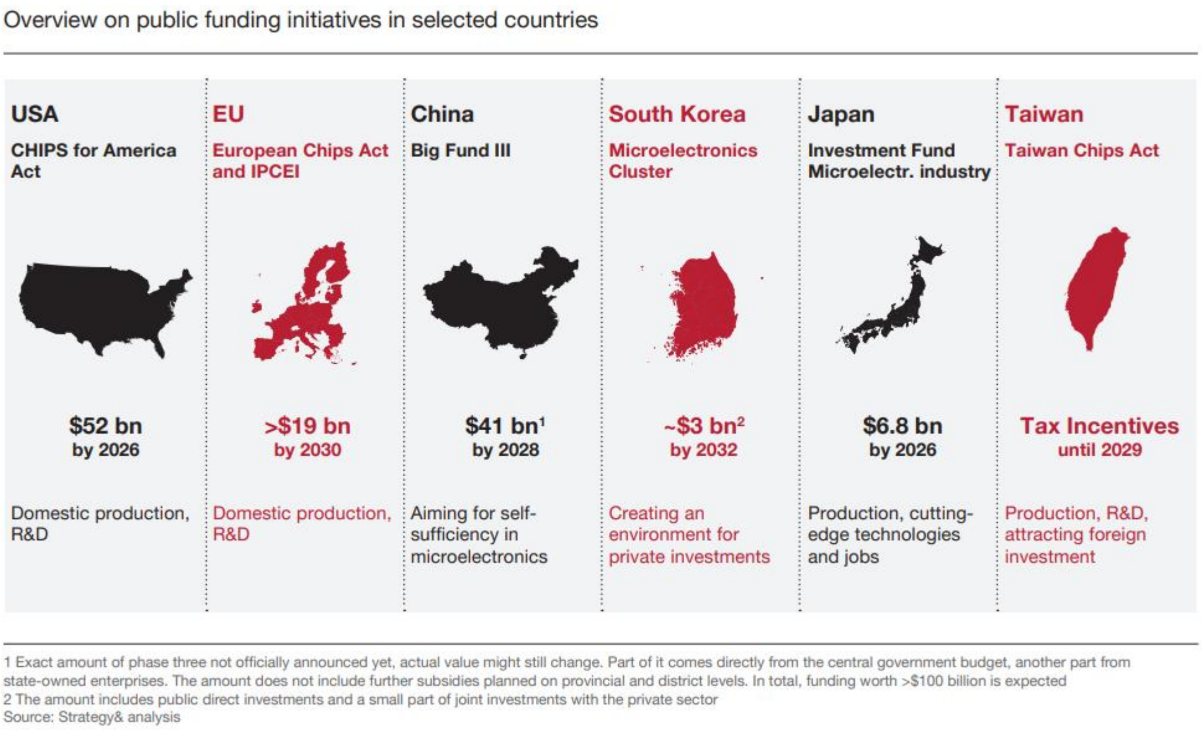


*Figure 2.11: Overview of public funding initiatives in selected countries*, screenshotted from Strategy & analysis (LinkedIn)

### 2.3.2 Europe is dependent on external suppliers in Asia.

President of the European Commission Ursula von der Leyen shared this in her speech when she announced the European Chips Act, 2023: "There is no digital without chips. [...] Europe's share across the entire value chain, from design to manufacturing capacity, has shrunk. We depend on state-of-the-art chips manufactured in Asia. So, this is not just a matter of our competitiveness. This is also a matter of tech sovereignty. So, let's put all our focus on it". This gave the region and nations in the union a strong geopolitical and technological sovereignty signal. It requires European countries to act properly to achieve the goal of the EU Chips Act.

Europe is the most dependent on external suppliers in semiconductor supply chains. It owns the technology in the Research and Design stage, but is out of control in manufacturing chips. Europe knows very well that during the shortage period, the COVID-19 pandemic and crisis in 2022 forced some car makers to shut down, costing nearly €100 billion only in the fiscal year 2021-2022 in the European automotive industry (TheBrusselsTimes, 2022). It requires Europe to react strongly and sharply to secure its role in the semiconductor value chains. After the US launched the CHIPS Act 2022, one year later, in September 2023, Europe announced the Europe Chip Act, aiming to reduce the EU's vulnerabilities and dependencies on foreign actors, improving the EU's security of supply, resilience, and technological sovereignty in the field of chips. With five focuses, the EU Chips Act aims to:

1) Strengthening Europe's research and technology leadership towards smaller and faster chips
2) Building and reinforcing capacity to innovate in the design, manufacturing, and packaging of advanced chips
3) Addressing the skills shortage, attracting new talent, and supporting the emergence of a skilled workforce
4) Developing an in-depth understanding of the global semiconductor supply chains
5) Putting in place a framework to increase production capacity to 20% of the global market by 2030

The objectives need to be achieved through three pillars of action:

1) **Research, Development, and Innovation**: By attracting large-scale investments, the "Chips for Europe Initiative" will support large-scale technological capacity building and innovation throughout the Union and enable the development and deployment of cutting-edge, next-generation semiconductor and quantum technologies.
2) **Security of Supply and Resilience**: A framework to ensure the security of supply and resilience of the Union's semiconductor sector will attract investments and enhance production capacities in semiconductor manufacturing, advanced packaging, testing, and assembly. Under this pillar, the Commission published guidance for obtaining the Status of an integrated production facility and an open EU foundry, which streamlines administrative processes and prioritizes access to pilot lines for semiconductor facilities.
3) **Monitoring and Crisis Response**: The European Semiconductor Board will serve as a coordination mechanism between the Member States and the Commission for mapping and monitoring the Union's semiconductor value chain and preventing and responding to semiconductor crises with ad-hoc emergency measures.

To achieve it, the EU set an investment of about €43 billion (~$45 billion) of policy-driven investment, which will be matched by long-term private investment. This investment focuses on:

- Research, Development, and Innovation in semiconductor technologies, e.g., chips smaller than 2nm, quantum chips…
- Support start-ups, scale-ups, and SMEs in accessing funding
- A more investor-friendly framework for establishing manufacturing facilities in Europe
- Fostering skills, talent, and innovation in microelectronics
- Tools for anticipating and responding to semiconductor shortages and crises to ensure the security of supply
- Building international semiconductor partnerships with like-minded countries.

The €43 billion package combines:

1) **Direct Grants:** €11 billion from Horizon Europe and Digital Europe programs for R&D.
2) **State Aid:** €22 billion national subsidies for Integrated production facility (IPF) certificated fabs: Vertically integrated facilities involved in the whole manufacturing chain; and Open EU foundry (OEF) certificated fabs: Facilities that dedicate part of their production capacity to manufacture chips for fabless companies (i.e. only focusing on chips design), subject to EU competition rules.
3) **Private Investment:** Leveraging €10 billion via the Invest EU Fund, with risk-sharing guarantees to attract venture capital.

Noticeably, 35% of grants are reserved for SMEs, fostering innovation in niche areas like automotive chips and IoT sensors.

The EU Chips Act showed the ambitions of Europe to double the EU's share of global semiconductor production from 10% in 2020 to at least 20% by 2030 when the global market value is projected to reach $1 trillion (EuropeanCommission, 2023). It means the EU will get about $200 billion in total semiconductor revenue in 2030, from around $50 billion in 2024; it requires the EU to grow triple in the next 6 years, with a compound annual growth rate (CARG) of 26%. It is a big challenge for the EU to achieve this goal in the global context of the tech war, especially when Trump is back as President with version 2.0, pushing America first and using tariffs and economic policy as a negotiation tool.

Alongside policy and legal actions, the EU has established the Chips Joint Undertaking – a dedicated investment platform to support semiconductor growth. This initiative will help the EU become a major player in semiconductor technology by supporting research, building necessary infrastructure, and attracting skilled workers. Recognizing the critical role of talent, the EU is also working to solve the skills shortage through training and education, ensuring that the union remains at the forefront of semiconductor innovation and manufacturing.

### 2.3.3 How is the EU dependent on the semiconductor supply chain in non-EU countries?

The EU depends significantly on foreign markets for particular products and technologies in their semiconductor industry. For making chips, according the Draghi's report in 2024 pointed out, 75-90% of global wafer fabrication capacity is in Asia (Draghi, 2024). While European companies are strong in chip manufacturing equipment (i.e., ASML) and research (i.e., IMEC), they rely on importing chip production and inter-media inputs from non-EU countries (CEPR, 2025). Additionally, the Ciani and Nardo research in 2022 showed that nearly 80% of the companies' suppliers have headquarters outside the EU, with around 35.9% located in the US, 12.4% in Taiwan, 11.7% in China and Hong Kong, 10% in South Korea, and nearly 9% in Japan (Ciani, 2022). Moreover, European companies have a significant share of their customers in semiconductors (63%) headquarters outside the EU (Ciani, 2022). The figure below details the import value of the 27 European countries (EU27) in specific semiconductor materials and products from non-EU countries. Most of the imports in the EU27 were the final product, accounting for 61.4% of the total import value, with 22% from Taiwan, 16% from Malaysia, and 14% from China. Others include raw materials, mainly from China and the US, inputs from South Korea and the US, and wafers from Japan and the US (see Figure 2.12).

| Segments | % imports | EU27 Import Value (€bn) | EU27 Export Value (€bn) | EU27 Trade Balance (€bn) |
|---|---|---|---|---|
| Raw materials for wafers | 0.8 | 0.7 | 1.8 | 1.0 |
| Inputs | 14.0 | 12.1 | 11.1 | -1.1 |
| Equipment | 21.6 | 18.7 | 45.2 | 26.4 |
| Wafers | 22 | 1.9 | 1.5 | -0.4 |
| Final products | 61.4 | 53.2 | 33.7 | -19.6 |
| Total | 100 | 86.7 | 93.2 | 6.4 |

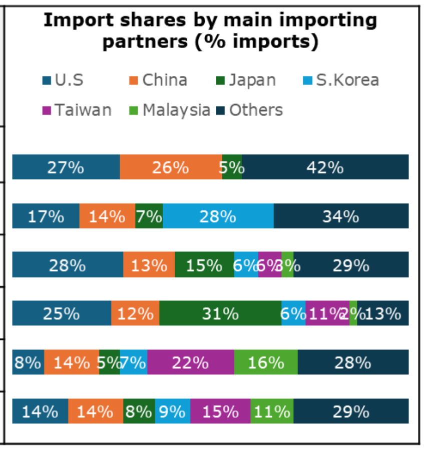


*Figure 2.12: Segments monitored along the semiconductor supply chain, 2023, adapted from [https://cepr.org/voxeu/columns/monitoring-framework-strengthen-eu-semiconductor-supply-chain#footnote1_2xi27td.](https://cepr.org/voxeu/columns/monitoring-framework-strengthen-eu-semiconductor-supply-chain#footnote1_2xi27td)*

Among EU-dependent countries, Taiwan is the most important in providing chips for the EU. Taiwanese Taiwan Semiconductor Manufacturing Corporation (TSMC) is the largest foundry company in the world, the most critical in the semiconductor industry, and the most important supplier to the EU. However, Taiwan's foundries rely much on European technology, such as ASML's unique advanced EUV lithography machines (Abalos, 2024).

Taiwan is well known worldwide for its highly successful high-tech industries, which have been the primary driving force of the national economy since the 1980s, and semiconductor manufacturing has unquestionably played the most significant role (Wang & Chiu, 2014). Nowadays, TSMC is in the top 10 largest companies by market cap and is the second largest company in the semiconductors industry, with over $1 trillion (companiesmarketcap.com, 2025), more significant than any European company in this sector. The semiconductor category also contributes critically to Taiwan's economy, with about 20% (see Figure 2.9). According to the

European Commission in the EU trade relations with Taiwan review published on its website, Taiwan was the EU's 13th biggest trading partner in 2023, and the EU is Taiwan's 4th largest trading partner after China, the USA, and Japan. Taiwan's total goods trade with the 27 European Union countries reached €77.7 billion. EU exports to Taiwan and EU imports from Taiwan amounted to €30.5 billion and €47.8 billion, respectively. In 2023, the largest category of trade between the two parties is semiconductors, with the EU exporting semiconductor machinery with 21% of total exports (€6,4 billion), 10% integrated circuits (€3 billion), while the EU imports are integrated circuits (microchips, etc.), which accounted for 23% of EU goods imports (approximately €11 billion). In terms of Foreign Direct Investment (hereafter FDI), the EU is Taiwan's largest FDI source, with US$ 58.1 billion invested between 1952 and 2023, including US$ 3.21 billion in 2023. Taiwan's outward FDI to the EU reached US$ 13.5 billion over the same period, with US$ 8.45 billion invested in the last five years alone (62.4%). During the period 2016-2023, two-way investment surged. Taiwan's EU investments increased 10.6 times, reaching US$ 10.85 billion, while EU investments in Taiwan grew 3.98 times, reaching US$ 31.71 billion, compared to the previous eight years (roc-taiwan, 2025).

However, the EU is one of the biggest choices in the tech war between the US and China, asking the Taiwanese government to navigate the fine line between them and the need to diversify partners (Shattuck, 2021). In August 2024, TSMC (Taiwan), Robert Bosch GmbH (Germany), Infineon Technologies AG (Germany), and NXP Semiconductors N.V. (Netherlands) made a joint venture together as named ESMC as the groundbreaking news and announced for the first fabrication plant in Dresden, Germany. When it goes to full operation, ESMC is expected to have a monthly production capacity of 40,000 300mm (12-inch) wafers on TSMC's 28/22 nanometer planar CMOS and 16/12 nanometer FinFET process technology, further strengthening Europe's semiconductor manufacturing ecosystem with advanced FinFET transistor technology, according to the joint venture press release (B. TSMC, Infineon, NXP, 2024). Total investments are expected to exceed €10 billion, consisting of equity injection, debt borrowing, and strong support from the European Union and German government (TSMC, 2024b). It remarked on the stronger relationship between the EU and Taiwan in the semiconductor industry, acting under the EU Chip Act strategy and navigating geopolitical challenges in technology sovereignty.

Another country that the EU relies on is South Korea, which is also located in Asia. The South Korean government has set semiconductors as the most important industrial sector in its economy. In 2024, semiconductors contributed 7.3% (see Figure 9) of total GDP, reaching approximately $142 billion (Digitimes.com, 2024), nearly 3 times the EU semiconductor size. Unlike the Taiwanese semiconductor foundry model, South Korea successfully used the IDM model led by Samsung within the country and globally. In 2024, Samsung's semiconductor revenue stood at 66.52 billion U.S. dollars, an increase from the 40.94 billion U.S. dollars in revenue recorded in 2023. Samsung benefited because of the memory semiconductor market, which experienced a rebound in 2024 (Statista, 2025). The revolution of South Korea in semiconductors began in the 1980s when the government decided to transform the economy by setting technology as the backbone of the economic ecosystem. The trading between the EU and South Korea in this industry has grown significantly in the last decade. South Korea is the EU's

8th largest export partner, while the EU is the third largest destination for goods in the South Korean market. The EU and South Korea signed a free trade agreement on 1 July 2011, called the EU-Republic of Korea Free Trade Agreement (‘FTA’ hereinafter) and formally ratified in December 2015, to make South Korea the first country that the EU has built a free trade relationship in Asia, make South Korea becomes one of the most important trade partners with the EU’s economy, according to European Commission public on the website. On 31 October 2023, to complement the FTA, the EU and South Korea launched negotiations for the digital trade agreement, with the ambitious setting modern digital trade rules, working on semiconductors, High-Performance Computing (HPC), and Quantum technology, 5G, and beyond, platform economy, artificial intelligence (AI) and cybersecurity (EuropeanCommission, 2024d). Since the trade agreement was implemented, total bilateral trade in goods amounted to €130 billion in 2023, up 106% from 2011, with €63 billion. The EU is the biggest FDI investor, with an FDI outward stock of €54 billion, while Korean investments into the EU have also grown and reached €40.6 billion in 2022. Korean investments are mainly focused on electric vehicles, with Hungary, Poland, and Germany being the largest investment places in 2022. In contrast, the EU invests in finance, insurance, and other professional services led by the Netherlands, Germany, and Luxembourg (EuropeanCommission, 2024d). According to the European Commission, South Korea is jointly investing in semiconductor projects with an investment of around €12 million, with equal contributions for both parties. The projects focused on Research and Innovation in advanced technology. This partnership will bring benefits to the EU by “allowing it to access some of the world's most advanced semiconductor technologies and manufacturing capabilities, complementing Europe's strengths in research and innovation” (EuropeanCommission, 2024b). Conversely, South Korean institutes will gain from the EU's leadership in research and innovation, including its emphasis on sustainable development.

### 2.4 Competitions within European Regions

The competition in semiconductors is not only in the global context but also in Europe. The leaders in this sector are the Netherlands, Germany, France, and Belgium. Those countries have similar corporate frameworks with strong relationships between the private sector and research institutions and receive substantial support from the government. These countries help the EU strengthen its strategic position, gain technological sovereignty, and stay competitive in the global market. The R&D expenditure of the EU and 4 of these countries increased, with the largest increase in the last five years being Belgium at 3,32%, followed by Germany at 3,11%, higher than the EU at 2,22%, while France and Netherlands are around 2% in 2023, according to Eurostat, the European Union's statistics office. The EU spent €381.4 billion on research and development in 2023, which is 6.7% more than in the previous year (€357.4 billion) and 57.9% more than in 2013 (€241.5 billion) (EraportalAustria, 2024).

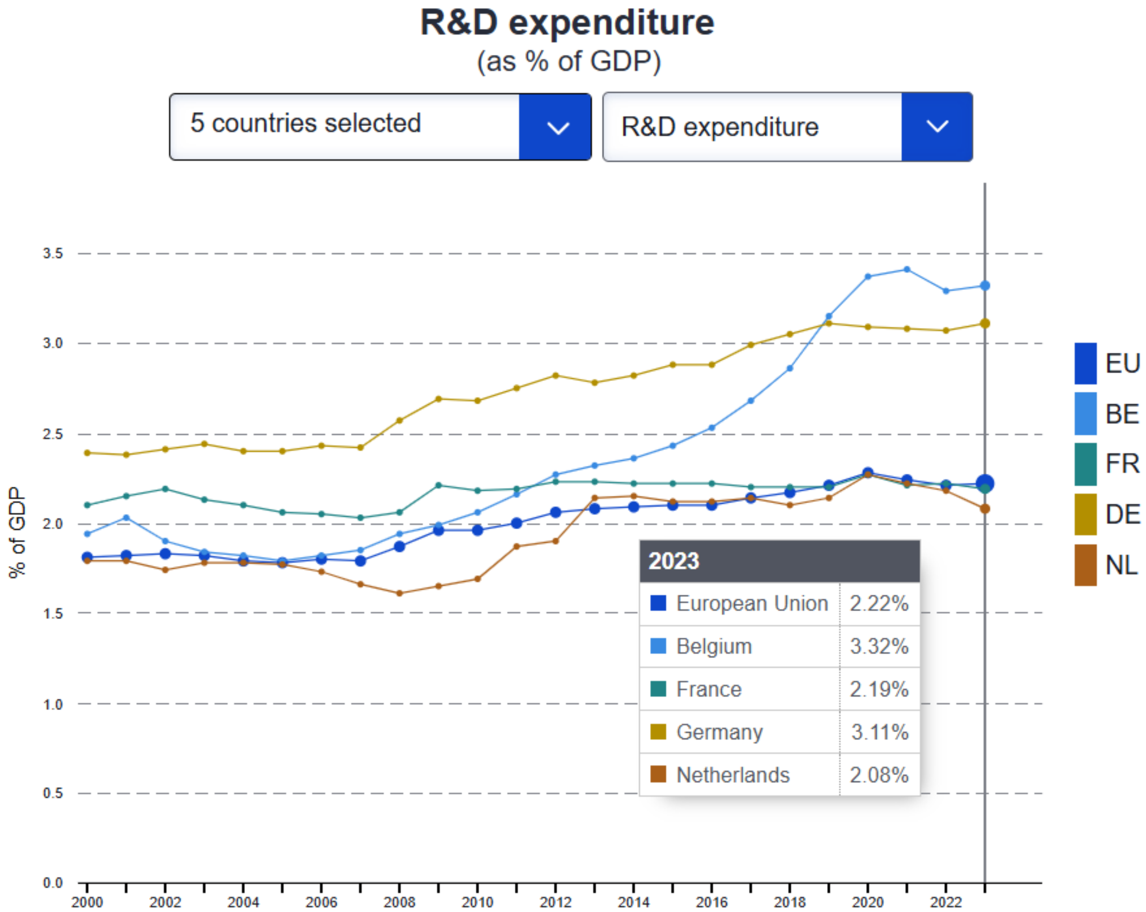


*Figure 2.13: R&D Expenditure in Europe.* Screenshotted *from the source: Eurostat (https://ec.europa.eu/eurostat/web/science-technology-innovation/visualisations)*

Regarding the Innovation Index, four countries also are in the high rank and stay competitive together, measured by Eurostat, with the Netherlands as the leader, while Belgium, Germany and France are strong innovators (EuropeanCommission, 2024f).

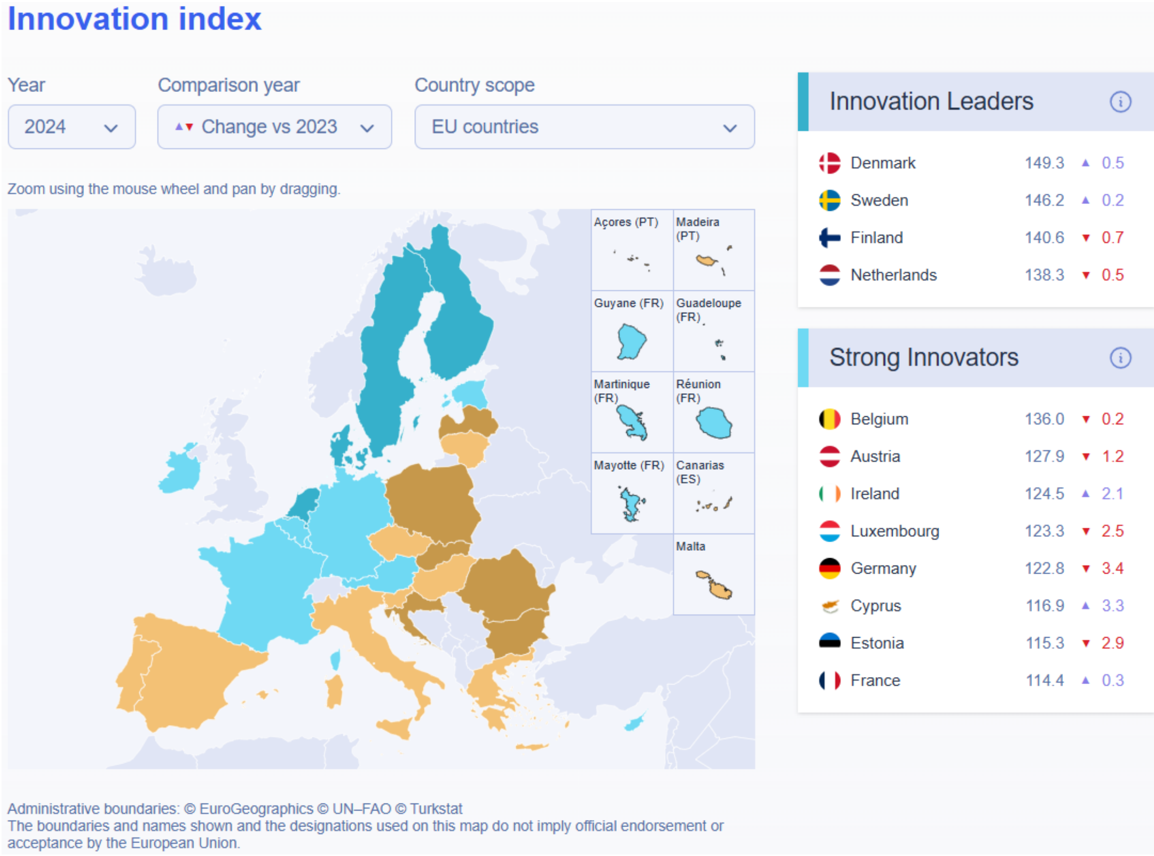


*Figure 2.14: Innovation Index in Europe.* Screenshotted *from the source: Eurostat, at* *https://projects.research-and-innovation.ec.europa.eu/en/statistics/performance-indicators/european-innovation-scoreboard/*

However, compared to operations in the US and Asia, the European industry has become relatively less innovative and less able to access the investment and entrepreneurship required to innovate(Huggins et al., 2022). The EU semiconductor industry is dominated by SME companies, with only 15 companies (4 Netherlands, 6 Germany, 3 France, and 2 Belgium) in the top 140 largest companies by market cap, last updated to the end of February 27, 2025 (companiesmarketcap.com, 2025), most of the rest are SMEs.

### 2.4.1 The Netherlands

The Netherlands is the leader with the most important company in ASML. The Dutch chip technology sector is crucial in global supply chains, advancing AI, IoT, and automotive tech innovations (Welcome-to-NL, 2024). As one of only three nations with a complete semiconductor value chain, the Netherlands is a top player in the global market, according to Del Maffeo, CEO, Axelera AI, a pioneer AI company in the Netherlands. The Netherlands has a leading role in three domains – Equipment, Specialty IDMs and Photonics. The Netherlands's semiconductor ecosystem is strong because they have an effective connection among three parties: public, private, and university partners. The Netherlands is in a leading position in this industry due to a unique history, with a long-lasting network of more than 300 companies. With more than four decades of development, through a close collaboration and "co-opetition (both corporation and competition) concept, it is difficult to be copied. Many of them are direct or indirect spin-offs from Philips, a leading technology company in the Netherlands since the 19$^{th}$ century, such as

ASML, ASM, NXP, and VDL. They have shared the same “DNA” and common background within the tech region to make them easier to connect, share and exchange knowledge and resources. As a result, many of the (senior) employees currently active in the Dutch semiconductor ecosystem share a way of working identified by close collaboration, long-term partnerships, and a give-and-take culture.

ASML is the largest and most important player in semiconductor value chains, owns lithography technology, an essential equipment in the production of chips. It is a multinational company headquartered in Veldhoven, the Netherlands, with offices across EMEA, the US and Asia, as informed on the company website. The company provides chipmakers with hardware, software, and services to mass-produce the patterns of integrated circuits (microchips). In 2024, ASML reached €28.3 billion in net sales, capital market value reached €300 billion, spent €4,3 billion on R&D, accounted for 15% of net sales value, and focused on increasing productivity on current EUV technology, developing the next generation of EUV and DUV technology to ensure the company is at the forefront of the technology, according to the publish on its website. ASML’s “installed-based-service business” will benefit from the growing installed machine base across the world and the increased demand for upgrades of existing machines (ASML has already sold over 5000 devices since 1984, and more than 90% of this installed machine base is still in operation). In parallel, there is an opportunity for ASML’s suppliers to benefit from ASML’s efforts to localize its repair and service business. Increasing geopolitical tension and export restrictions could impact ASML’s growth trajectory, according to PwC’s semiconductor report in the Netherlands (pwc, 2024).

NXP Semiconductor is another important company, with leading in specialty IDM, focus on production advanced chips with product groups that are focused on four end-markets that are characterized by long-term growth opportunities: (1) **automotive** (with autonomous driving, electrification and the “service oriented” car), (2) **industrial & IoT** (driven by demand of smart, energy-saving and connected electronic equipment using various sensors, processors, connectivity, analog and security chipsets that align well with NXP’s ability to provide a complete range of processing, connectivity and secure solutions), (3**) mobile** (leveraging NXP’s focus on mobile wallet, Ultra-Wideband (UWB) and specialty custom analog solutions), and (4) **communication infrastructure** (transition to 5G networks and cloudification, and increased demand for secure edge identification solutions), according to PwC semiconductor report (pwc, 2024). The company achieved $12.61 billion in revenue for the full year 2024, and its market cap is around $58 billion. It spent $2,35 billion in R&D (18.6% of revenue), which shows the strong commitment to continue investing in new technology and pushing ambitious investments to achieve its goals (NXP, 2024).

The Netherlands government support the High Tech Campus, located in Eindhoven, Netherlands, is built around an ecosystem of 300 companies with a range of application fields, over 12.500 innovators, researchers, and engineers; focus on 5 key areas: Health & Vitality, Software & Platforms, Applied Intelligence, Smart Environments & Connectivity, and Sustainable Energy & Storage. It is recognized as the smartest square km in Europe (Hightech-campus-Eindhoven, 2025). With this tech hub, it connects and serves as a platform to exchange, experiment and scale-up new technologies through the Open Innovation frameworks. It promises a strong positive vision for the Netherlands's semiconductor ecosystem.

### 2.4.2 Germany

While the Netherlands is a leader in some critical value chains, Germany is well known for its traditional semiconductor production and a large consumption market. Germany is a net importer of semiconductors. In detail, Germany imported memories and product sensors, mainly from Taiwan, and semiconductor devices, significantly from China (KFWResearch, 2024). The country is getting substantial subsidies from the government to modernize domestic semiconductor production facilities and reduce dependence on Asian and the US suppliers, the fund is €2 billion, released by the government in late 2024. The country has also announced ambitious investment plans for the domestic production of semiconductors – a 2025 timeline has been agreed for Europe to develop its own leading-edge processor chips. Germany wants the European chip industry to invest up to €50 billion in semiconductor production to establish European digital sovereignty. Research from Germany Trade & Invest showed that Germany received 10 of 16 investment microchip projects in the EU. It illustrates that Germany is the destination for the microchip production stage at a large scale, not only for the EU, but also for the global supply chain.

In the top largest semiconductor companies, Germany has six, with a market valuation is around $56 billion (companiesmarketcap.com, 2025). The largest semiconductor company in this list is Infineon, with a valuation of $50.3 billion. Infineon is an IDM model, a leader in power systems and IoT, focusing on green technology and decarbonization. The company is a leader player in power semiconductors and a leading power systems innovator with provides silicon-, silicon-carbide- and gallium-nitride-based power, driver, microcontroller, and software solutions are essential to take energy efficiency and green power to the next level; one-stop technology partner for smart, energy efficient, and secure IoT solutions, supply sensors, microcontrollers, and communication devices combined with security technologies and related software are indispensable in bringing the industrial and consumer IoT to life (Infineon, 2025). Infineon's revenue was about €15 billion in 2024, R&D spending was €1.99 billion, accounting for 13.3% of revenue. Compared with the investment budget in this industry, Infineon was at the middle level, which is expected to increase in the future.

Germany semiconductor ecosystem has Fraunhofer Institute for Applied Solid State Physics (Fraunhofer IAF hereafter), as a cooperation between the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP, the Research Fab Microelectronics Germany (FMD) is the central point of contact for all issues concerning research and development in the field of micro and nanoelectronics in Germany and Europe (IAF, 2025). Its vision is a global innovation driver and the largest cross-site R&D cooperation for micro and nanoelectronics in Europe. It offers a unique range of competences and infrastructures. Fraunhofer IAF contributes to the compound semiconductors to realise highly efficient, resource-saving and secure solutions, also in advanced future technologies such as quantum computing and 6G in Europe. This innovation hub is also partnering with companies in this field and governments to initiate a program to support start-ups, focusing on the joint development of demonstrators and prototypes, also strengthening the business model, called FMD-Space. With this research hub and connecting with strong network semiconductor companies, combined with a high demand for the consumption economy, the largest population and biggest economy in Europe, Germany is expected to be the leader in terms of both innovation and generating business size.

### 2.4.3 France

France is one of the rising countries in setting up semiconductors as the fuel of the economy. France government announced an investment €30 billion plan to create France's future technological champions in sectors such as semiconductors, robotics, electric vehicles, nuclear and renewable energy sources, in which €6 billion for semiconductor under the **France 2030** plan, targeting a doubling plan targets a doubling of electronics production by 2030 and leadership in sub-2nm chip development (EETimes.eu, 2021). The Crolles mega-fab, backed by €2.9 billion in state funding, began operations in 2023, leveraging Grenoble's concentration of semiconductor expertise from firms like Soitec and research institute CEA-Leti (bpifrance.com, 2023). This facility aims to produce advanced logic chips for AI and automotive applications, reducing reliance on Asian foundries.

The largest semiconductor company of France is Soitec, which plays a key role in the microelectronics industry. This is the world-class leader in innovative semiconductor materials. Soitec has been developing cutting-edge products combining technological performance and energy efficiency for over 30 years, according to the company website. The Group is expanding internationally to serve three main strategic markets: mobile communications, automotive and industry, and smart objects. More than 92% of the company's revenue comes from outside France, spends around 11% on R&D, and the market valuation is $2,3 billion in the latest tracking (Soitec, 2025).

With an aggressive mindset to gain more in technology sovereignty and a strong commitment from the government, the semiconductor ecosystem will be developed significantly in the next phase.

### 2.4.4 Belgium

Belgium is not only the center of the EU, but also a research and innovation hub in the global semiconductor industry, with a well-known research and innovation hub, IMEC. IMEC was founded in Leuven, a university city in Belgium. It is a foundation of global semiconductor research, specializing in advanced node development, photonics, and packaging technology. Today, it is the world's largest independent research and innovation center for nanoelectronics and digital technology. With a worldwide team of 6,000 scientists, engineers, and innovators from over 100 countries, using an Open Innovation model, IMEC works side by side with all ecosystem players in a neutral and Open Innovation model (IMEC, 2025). It partners with all the top semiconductor & innovation institutions in the world, from ASML (Netherlands), TSMC (Taiwan), Intel (the US), and Samsung (South Korea) …and also partners with startups, over 200 universities to bring the gap between the labs and the market. It also has offices in the Netherlands (the One Planet Research Center and Holst Center), UK (located in Cambridge), and in the US (Florida, Indiana, Michigan). Under the IMEC initiative, more than 300 tech start-ups have already emerged through the accelerator program imec.istart; raised almost 1 billion euros in follow-on funding; The imec.xpand fund collected more than 400 million euros for start-up investments in deep tech; several of more than 120 spin-offs that IMEC has founded are gradually growing into successful companies in the future; and provides more than 13,400 jobs, of which 2,900 are in spin-offs, according to IMEC public (IMEC, 2025).

Belgium contributes two companies to the top largest market valuation list with Melexis and X-FAB. Melexis is a global supplier of micro-electronic semiconductor solutions, mainly focused on semiconductors for the automotive industry, providing sensors, solutions to make cars and other products smarter, safer, and greener. Melexis has a value of $2.61 billion, revenue in 2024 was $1 billion, and R&D expenses were 11.8% of sales (Melexis, 2025). Another Belgian company in the list is X-FAB. This company is a global foundry group providing a comprehensive set of specialty technologies and design IP to enable its customers to develop world-leading semiconductor products that are manufactured at X-FAB's six wafer fabs located in Malaysia, Germany, France, and the US; expertise in analog/mixed-signal technologies, microsystems/MEMS and silicon carbide (SiC), X-FAB is the development and manufacturing partner for its customers, primarily serving the automotive, industrial and medical end markets (X-FAB, 2025).

In summary, the EU has declined their market share in semiconductors from 24% of global production capacity in 2000 to just 8% today (EuropeanCommission, 2023). The EU has a strong position to take advantage of investing and gain market share back in the future. Through a multiple strategic decision such as enacting the EU Chips Act 2023, an ambitious and focus of leading European economies (i.e the Netherlands, Germany, France) and the largest innovation institutions such as IMEC, High Tech Campus, Fraunhofer, CEA-Leti, these help the EU build a stronger semiconductor ecosystem to recover their position and share the contribution in navigating global geopolitical challenges.

### 2.5 Emerging semiconductor markets in reshaping the global supply chain strategy

During the rise of geopolitical challenges, especially when Trump’s government is aggressively using tariffs and controlling exports as a new power tool to reshape global trade relationships. The investment has been shifting to third countries, outside the US-China relationship, such as Vietnam, Malaysia, and Singapore. In the context of reducing dependence on the EU in semiconductors in countries as Taiwan and South Korea, the EU should consider these countries as the next destination to invest in semiconductors. Additionally, like Vietnam, it is one of the most dynamic economies in the world and has emerged as a pivotal player in this sector. Vietnam has a comprehensive strategic partnership with both China and the US, and also has the same level of strategic partnership with France, the second-largest economy in Europe. It gives Vietnam a unique position to build relationships, attracting FDI and creating a win-win long-term partnership. Vietnam is leveraging its unique strategic position to attract investment to build the next hub for semiconductor manufacturing and innovation. Vietnam's semiconductor market is projected to reach $7.01 billion by 2028 (sourceofasia.com, 2024), supported by aggressive government policies, a young STEM-oriented workforce, and deepening partnerships with both the US and China. In late September 2024, Prime Minister Pham Minh Chinh launched Vietnam's semiconductor strategy (Decision 1018) with strategy concept C = SET +1, in details C = Chip, S = Specialize Chips, E = Electronics (focus on product type), T = Talent (developing specific talent for semiconductor field) and 1 is represent for Vietnam as a new destination with safe and attractive place, aiming to establish the country as a global leader semiconductor by 2050 (VietnameseGovernment, 2024). The strategy outlines three development phases, with the first (2024-2030) focused on attracting targeted FDI and building key infrastructure: 100 design firms, a small fabrication plant, and 10 packaging/testing facilities, alongside developing specialized semiconductor products. Many large global semiconductor companies have already made significant investments in Vietnam. Among these are projects worth hundreds of millions of USD, even billions of USD, such as those from Intel set up the largest ATP (Assembly, Testing, Packaging) factory, located in Saigon Hi-Tech Park in Ho Chi Minh City, South Korea's Hana Micron is investing $1 billion in Bac Giang province, while Amkor and Qualcomm are scaling R&D operations (asiamattersforamerica.org, 2024). In late 2024, the CEO of NVIDIA also visited Vietnam and made a cooperation agreement between the Government of Vietnam and the US chip giant on the establishment of an artificial intelligence (AI) research and development center and an AI data center in Vietnam. In addition, several domestic companies, including Viettel, FPT, and VNChip, have actively entered the semiconductor industry market, according to the Investment and Trade Promotion Center of Ho Chi Minh City (ITPC, 2024). Moreover, the U.S.-Vietnam Comprehensive Strategic Partnership has accelerated technology transfers, with the CHIPS Act facilitating workforce training programs targeting 50,000 engineers by 2030, also from the ITPC source. Vietnam and the EU relationship is rising stronger through strategic moves such as signing the FTA on 30 June 2019 and increasing FDI. Vietnam was the EU's 17th biggest trade-in-goods partner and the EU's largest trading partner in goods in the Association of Southeast Asian Nations (ASEAN) in 2023, with total trade flows amounting to €64.2 billion. With a total FDI outward stock of €13.8 billion (2022), the EU is one of the largest foreign investors in Vietnam (EuropeanCommission, 2024c). The largest sector of investment by the EU is industrial processing and manufacturing. With the strategic position in the global economy and the ambitious goals of the government in the semiconductor sector in the future, Vietnam is becoming the most attractive destination for investors in the coming years, especially for the EU in navigating the global tensions in this field.

## 2.6 Theoretical Frameworks

The semiconductor ecosystem is considered the most complex and tremendous application of technology knowledge today. It cannot be done by any single party in the ecosystem. This ecosystem requires three major parties to be involved, including the Public (Government), the Private (Semiconductor firms), and Academia (Institutions), to research and develop new innovations.

### 2.6.1 Triple Helix Theory

The Triple Helix Theory of Innovation, pioneered by Henry Etzkowitz and Loet Leydesdorff in the 1990s, redefined how societies approach economic development by emphasizing dynamic interactions among academia, industry, and government. The Triple Helix model presents three types of models, in which the difference lies in the changing relationship between state, industry, and academia. In the first mode, the dominant role of the State controls the whole ecosystem and is very limited for bottom-up parties, Industry, and Academia. This is a traditional country model, similar to the former Soviet Union. The second mode consists of separate institutional spheres with strong borders dividing them and highly circumscribed relations among the spheres, exemplified in Sweden by the noted Research 2000 Report and in the US in opposition to the various reports of the Government–University–Industry Research Roundtable (GUIRR) of the National Research Council (MacLane, 1996; cf. GUIRR, 1998). The third mode is a dynamic model where three parties overlap and collaborate. The last mode is the most common in today's world: realize an innovative environment consisting of university spin-off firms, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms (large and small, operating in different areas and with different levels of technology), government laboratories, and academic research groups (Etzkowitz & Leydesdorff, 2000).

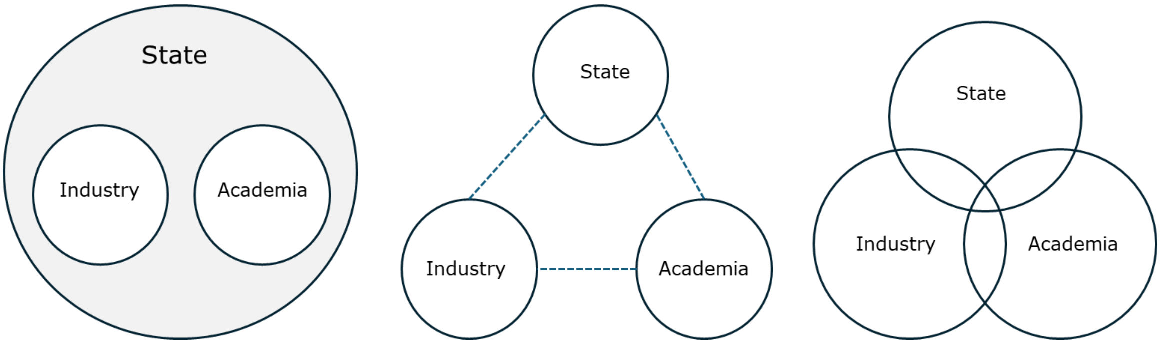


*Figure 2.15: Triple Helix State-Industry-Academia Relationship*

The model comprises three helices:

1) **Academia (Universities):** Traditionally focused on education and basic research, universities evolved into "entrepreneurial institutions" through patenting, spin-offs, and industry partnerships.
2) **Industry (Firms):** Firms commercialize research outputs and capture economic value but increasingly engage in collaborative R&D and co-fund academic projects.
3) **State (Governments)**: Beyond policies and regulations, governments act as innovation catalysts through policy, funding, and infrastructure development.

The helices interact through bilateral and trilateral partnerships, fostering hybrid institutions like technology transfer offices (TTOs) and science parks.

The Triple Helix concept extends beyond the interactions between universities, industries, and governments, acknowledging the internal transformations within each. The university has been "transformed from a teaching institution into one which combines teaching with research." (Etzkowitz & Leydesdorff, 2000). This model is exemplified in many countries, such as the US and the EU, and is now rising in Asian countries (i.e., South Korea, Taiwan…).

### 2.6.2 Public-Private Partnership Framework

The public-private Partnership Framework (PPP) is a collaborative model in which governments and private entities jointly finance, develop, and manage projects to achieve public goals, leveraging private-sector efficiency and oversight. This framework shares risk and investment between two parties (governments and the private sector) based on each party's capacity to manage them in long-term partnerships. The most common type of this framework is Build-Operate-Transfer (BOT), which is usually used in building infrastructure such as roads, railways, and canals. This framework is usually used in industries that require intensive investment and complexity, and involve many suppliers and resources to operate and produce. Because of this nature, these industries or activities are important and greatly benefit people and nations. It is also a long-term strategy, asking to carefully prepare and execute plans. The semiconductor industry is no longer purely a technology asset but is critical for national security and economic competitiveness. It requires the PPP framework to build and secure its infrastructure for the economy, especially to make a large-scale business in this industry. Multiple countries are using this as the analysis in the previous part of this thesis, such as the US Chips Act, the EU Chips Act, or Belgium's IMEC research center.

### 2.6.3 Purpose-oriented public-private partnership led by Professor Mariana Mazzucato

A well-designed mission-oriented industrial strategy can be an engine for economic growth (Mazzucato et al., 2024). In the research, she proposed that welcoming the underlying uncertainty and experimentation that solutions to complex problems require, rather than derisking, is required. A fundamental change is needed: public financial institutions should be viewed as primary investors, not just backup lenders. Industrial policy is considered "an engine for driving economic-wide growth." Her research explained that governments use industrial strategy, a combination of supply and demand-side interventions, to achieve economic objectives. Supply-side tools, such as subsidies and tax credits, encourage investment in R&D. Demand-side measures, like public procurement, create market opportunities. Industrial strategy can focus on specific sectors (vertical) or broader economic conditions (horizontal). Effective strategies combine these approaches and integrate them with other policies, such as education and environmental regulations, to enhance competitiveness and sustainability. A paradigm shift is needed in government-business partnerships. Instead of fearing business departures, governments should focus on creating partnerships with shared objectives and mutual benefits. By setting conditions on public support, governments can ensure public value alongside private profit. These conditions can include ensuring equitable access to products and services, directing business activities towards social goals like carbon reduction, requiring profit-sharing through royalties or equity, and mandating reinvestment in R&D or worker training instead of shareholder buybacks. This shift from redistributive to pre-distributive policies, using conditionality, creates a more symbiotic government-business relationship. Under this definition, the US Chips Act 2022 or the EU Chips Act 2023 are examples of driving purposes in the semiconductor industry. Instead of subsidizing only, the Chips Act program focuses on a comprehensive approach to getting involved in multiple stages of building and developing the semiconductor field, from supporting current semiconductor firms, encouraging new start-ups, connecting research institutions with businesses, fostering training and creating a new labour pool for this industry.

### 2.6.4 Open Innovation Model

Innovation is the term used to describe the invention, implementation, and bringing to market. (Chesbrough, 2003). The innovation can be commercialized and address the market's needs. Thus, innovation faces the challenges of 1) being hard to predict, not only the technology itself but also the technology-in-use, and 2) demanding an innovative business model to meet the innovative product offering. In Chesbrough's 2003 book, he introduced the concept of an Open Innovation scheme as one of the most essential frameworks in technology and business today. The Open Innovation model proposed a new idea to manage innovation. "Instead of controlling technology within the firm, called the "Closed innovation" model, Open innovation suggests using purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively" (Chesbrough, 2006). This approach recommends that firms should actively reach out and leverage both internal and external knowledge and innovation to foster their technologies and bring them to market. Implementing an Open Innovation model links three ways to turn new technology value into economic value: 1) incorporating this technology into the current business; 2) licensing out the intellectual property of its technology; and 3) launching new ventures that exploit the technology in new business areas.

**Why does an Open Innovation model become critical in technology such as semiconductors?**

Firstly, semiconductors are high technology knowledge with complex expertise from various fields such as materials, equipment, lithography, wafers, and layers…which cannot be owned by one firm or a country. It required extensive collaboration, from research to design to production, testing, packaging, and commercialization. Using open source to allow the firms to utilize the technology from other firms or intellectual property agents to be co-producers fosters productivity, especially in sophisticated products like chips. With more than 1,000 steps needed to produce one microchip, extreme technological development is required; it continuously asks the whole value chain to improve and develop to have a better version.

Secondly, making chips requires a massive investment, which means it is too expensive for any single firm or government to afford. The Open Innovation model supports the building semiconductor industry in reducing the risks for the entire value chain, both the research and development and the production cost, and increasing productivity in terms of time, cost, and quality of technology development. It can also be used to boost start-ups and scaling-up stages. Today, new start-up companies are accompanied by the increasing quality and productivity of university research. The knowledge will be "split out very quickly through research laboratories, with significant pools of expertise distributed among companies, customers, suppliers, universities, national labs, industry consortia, and start-up firms" (Chesbrough, 2003).

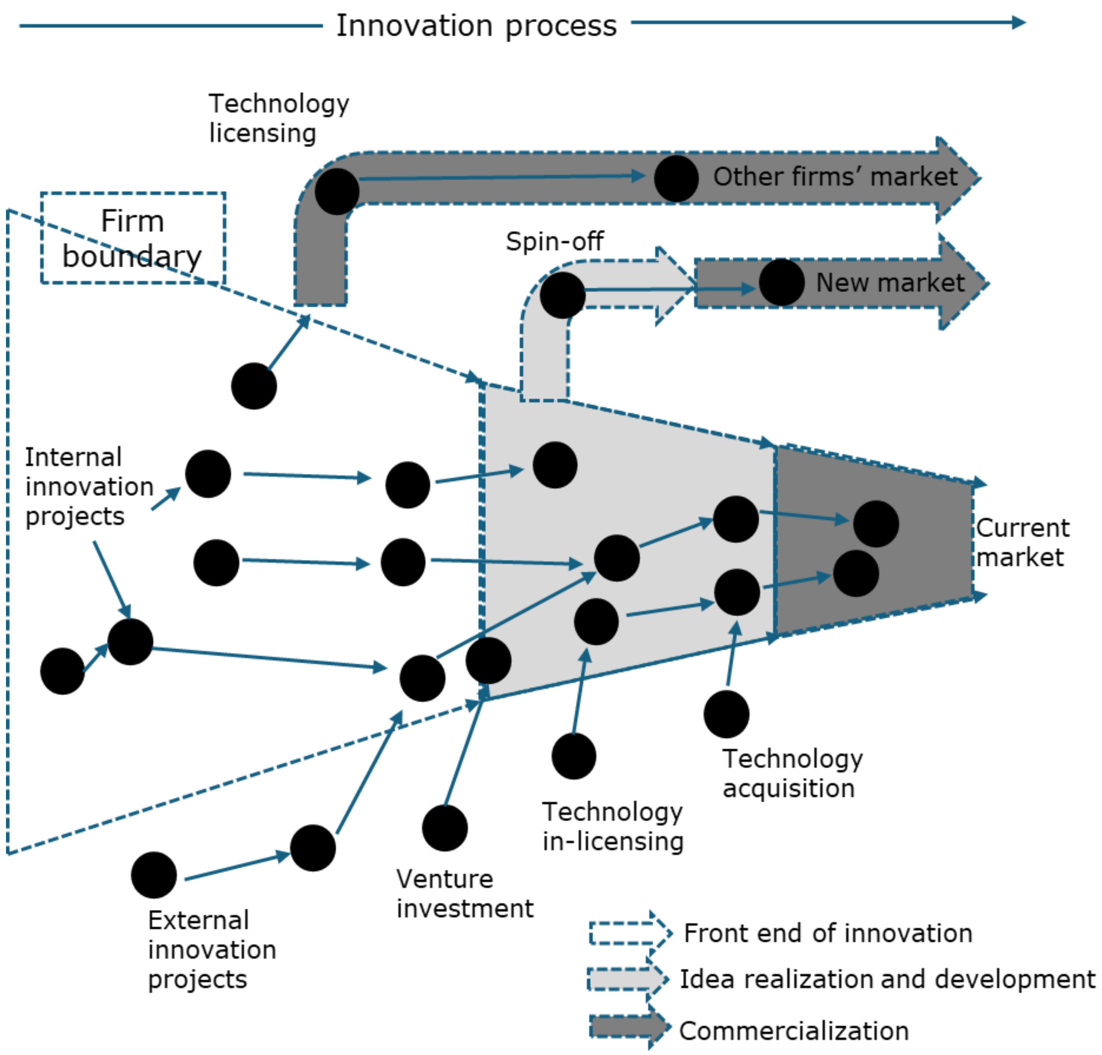


*Figure 2.16: Open Innovation Model application in semiconductor, adapted from Herzog, 2011*

The Open Innovation framework is used throughout the semiconductor supply chain, especially in the Research & Development phase with innovative institutions such as IMEC (see Figure 2.17), Fraunhofer, CEA-Leti, and High-Tech Campus Netherlands. On the business side, TSMC is the leading foundry firm also applying an Open Innovation framework with TSMC's Open Innovation Platform® (OIP) (see Figure 2.18), integrating 11,000+ ecosystem partners to reduce 5nm node time-to-market by 40% compared to closed development (TSMC, 2025).

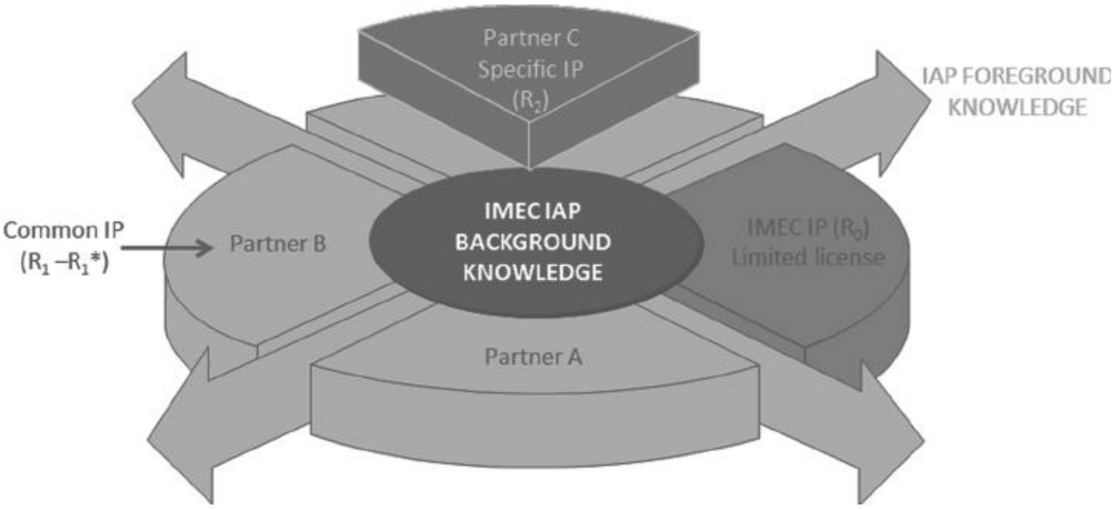


*Figure 2.17: Open Innovation Framework applied in IMEC IAP, 2024*

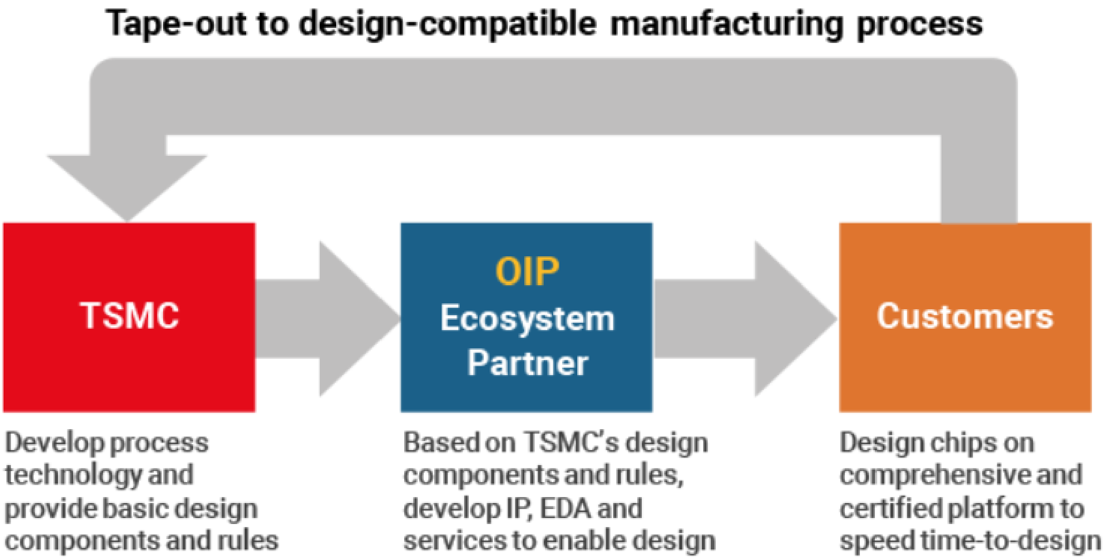


*Figure 2.18: Open Innovation Framework applied in TSMC,* screenshotted *from the TSMC's website, 2025.*

Open Innovation 2.0 was introduced by Dr. Martin Curley, Vice President and Director of Intel Labs Europe, Intel Corporation; Professor of Innovation, Maynooth University; Chair of EU Open Innovation and Strategy Policy Group. Open Innovation 2.0 is a new paradigm based on principles of integrated multidisciplinary collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies, and a focus on innovation adoption (Curley, 2015). In this extended framework, the parties increase to four; the end-user is a new participant in the OIEs (see Figure 2.19).

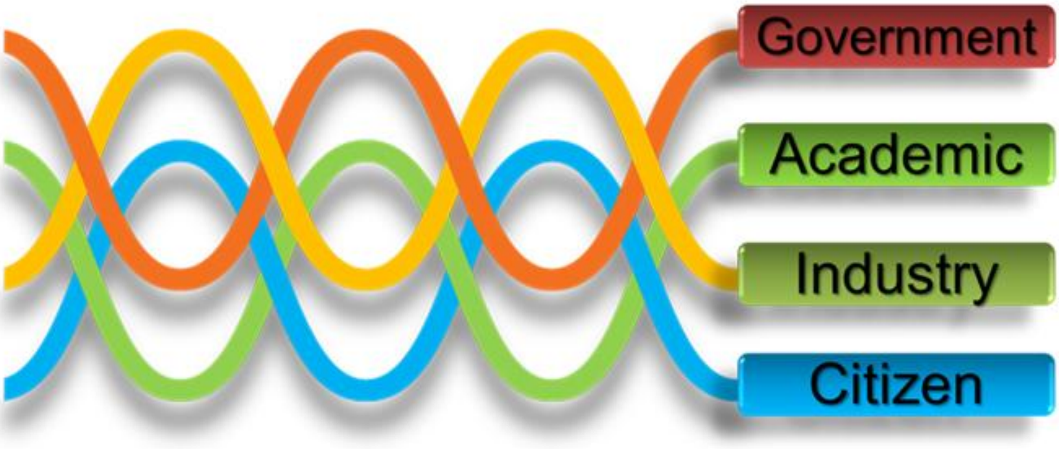


*Figure 2.19: Open Innovation 2.0, adapted from Dr. Martin Curley, 2015.*

A discussion about the reasons for starting open innovation, especially in developing new products or services, was conducted by Professor Vanhaverbeke Wim and Gilsing Victor (2023). In this development, open innovation has two modes: outside-in and inside-out. Outside-in open innovation has received much more attention both from practitioners and academics. (Vanhaverbeke & Gilsing, 2022). They proposed four scenarios: financial return focus in outside-in mode, financial return focus in inside-out mode, strategic return focus in outside-out mode, and strategic return focus in inside-out mode. Based on these suggestions, the semiconductor industry can apply multiple strategies to generate results according to the development purpose.

| **Reason to start open innovation** | Outside-in | Inside-out |
|---|---|---|
| Strategic return | **Developing your new products & services**<br>- Collaboration with technology & market partners/crowds<br>- Building the infrastructure<br>- Incentivize others to share innovations | **Enable your (potential) partners to innovate**<br>- Selective revealing<br>- Opening background IP to partners (co-development)<br>- Spin-offs (reacquisition)<br>- Incentivize others to innovate |
| Financial return | **Improving your operations (process innovations)**<br>- Factory 4.0 labs<br>- Suppliers<br>- Digital transformation<br><br>Operational input - terminology | **Monetizing your internal technology**<br>- Licensing<br>- Spin-offs<br>- … |

**Open innovation mode**

*Table 3: Open Innovation classification of different objectives to be pursued, adapted from Vanhaverbeke Wim and Gilsing Victor (2023).*

Geopolitical tensions today have threatened any company and country globally due to uncertainty. An open innovation scheme helps firms or ecosystems to be more dynamic than closed innovation, which will help them face the unexpected more efficiently. Open innovation frameworks will help to strengthen ecosystems by connecting all partners in the value chain. It is one of the most important microchip ecosystems today.

### 2.7 Challenges in applying Open Innovation in Europe

In Draghi's report released in 2024, he noted that the first – and most important- "Europe must profoundly refocus its collective efforts on closing the innovation gap with the US and China, especially in advanced technologies" (Draghi, 2024).

#### 2.7.1 Regulation Impacts on Innovation

The European Union is a unique example of voluntary integration among sovereign nations. Its formation began in the 1950s with six founding states, expanded to fifteen in the 1990s, currently includes twenty-seven member nations, and is adding new members. The European Union's framework does not follow a standard international organization, such as the United Nations or the World Trade Organization, nor does it follow a federal state, like the United States, or a centralized-state like China. While the EU shares some attributes with a state, particularly its significant independent executive, legislative, and judicial authority, it maintains a unique identity. "However, unlike a federal "state", the EU's member state governments remain the sovereign signatories of the EU treaty, the budget of the EU remains small, the EU relies on the voluntary compliance of the member states for the enforcement of the EU law, the member state remains sovereign in many areas of policy (including the ability to sign international treaties), and an "intergovernmental body" – the European Council, which brings together the heads of state and government of the EU member states – has taken an increasingly central role in EU decision-making" (Hix & Høyland, 2022). Under certain conditions, regulation can contribute as a powerful channel to support for innovation and entrepreneurship. However, its general effect depends on the "balance between innovation-inducing factors and compliance costs generated by regulation" (Pelkmans & Renda, 2014). Also, in the research of Pelkmans & Renda 2014, the research pointed out that "EU regulation matters at all stages of the innovation process, from R&D to commercialization". The research also showed that, regulations can be categorized based on their influence on innovation: "general or horizontal, innovation-specific and sector-specific regulation". Restrictive regulations often hinder innovation, while the flexible EU model tends to encourage innovation. Reducing the burdens of compliance and administration also affects innovation (Pelkmans & Renda, 2014). EU regulation stays as "complex" and "partly contradictory" requirements on companies as the European Union president, Ursula von der Leyen, pointed out in recently and sent a commitment to simplification by cutting regulations and boost innovation in an attempt to reserve Europe's economic decline and better compete with the US and China (Guardian, 2025). Her initiative is to "reduce reporting requirements by at least 25% (and 35% for SMEs), and her mission letters mandate the Commissioners to contribute to this endeavour and perform the "stress test" of the entire EU acquis". In the State of European Tech 2024 report, they claimed that "47% of the survey respondents see excessive bureaucracy as the one change that needs to be addressed for Europe to be able to reach its full potential in the next decade". Additionally, Financial industry veteran - and now Danish MEP - Stine Bosse said that "the issue (of the EU) is not necessarily the amount of public funding but rather structural problems, like burdensome regulations, that are holding back EU competition and company growth". She also highlighted that "navigating disparate national rules for company establishment and product commercialization delays time-to-market for European firms, eroding their competitiveness against streamlined U.S. and Chinese rivals" (Science & Business, 2024).

In Draghi's report, he also called out that "….but innovation is blocked at the next stage: we are failing to translate innovation into commercialization, and innovative companies that want to scale up in Europe are hindered at every stage by inconsistent and restrictive regulations" (Draghi, 2024).

### 2.7.2 Weak in scaling up in applying Innovation

In the 10th anniversary edition, released by 2024, the State of European Tech 2024 report shared that over the past decade, Europe has underfunded its growth companies to the tune of $375 billion, which still does not come close to the trillions invested in the US (Stateofeuropeantech, 2024). However, investment trends show significant growth; European startups and scale-ups received $426 billion in the period 2015-2024, compared to the 2005-2014 period, which raised $43 billion, nearly ten times. This report highlighted that pension funds and major insurers, which are currently investing just 0.01% of their $9 trillion capital budget in European venture capital, are the beginning of the solution. Although Europe is becoming "a global hotspot for early-stage startups, it now hosts around 35,000 early-stage companies, more than any other region; startups face considerable obstacles in scaling beyond the early stages due to regulatory complexities, talent shortages and a significant growth funding gap" (Stateofeuropeantech, 2024). The European Innovation Council (EIC) announced that it would invest €1.4 billion in deep-tech research and high-potential start-ups to support this bottleneck in 2025 (EuropeanCommission, 2024e). EIC Fund's equity will fund €10 - 30 million through the STEP Scale Up program, targeting later-stage scaling. The State of European Tech survey also shared that investment capital and funding dynamics need to change to help European tech companies reach their full potential in the next decade.

## 2.8 Challenges in emerging technologies and their impact on the semiconductor industry

### 2.8.1 AI is accelerating new technologies

What is Artificial Intelligence? According to the Computer Science Department at Stanford University, "it is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable". The intelligence referred to is the computational part of the ability to achieve goals in the world (McCarthy, 2007). By January 2023, Chat GPT published to market and became the fastest-growing platform with reaching 100 million users after just two months launching, and it created a new wave for generative AI with many competitors today, with key players Google Gemini (US), Microsoft Copilot (US), Deepseek (China) and Grok (US) just released (Elon Musk's AI). Generative AI enables users to quickly generate new content based on a variety of inputs. Inputs and outputs to these models can include text, images, sounds, animation, 3D models, or other types of data (NVIDIA, 2025). The technologies used to build generative AI include machine learning (ML) and deep learning. These technologies require advanced chips to handle a significant calculation for one prompt in generative AI. Developing and maintaining generative AI models presents significant practical challenges due to their sheer size and complexity. This includes building rapid data pipelines, securing substantial capital, employing highly skilled AI practitioners, and deploying massive computing power. Training diffusion models, for example, requires access to vast image datasets and the ability to utilize hundreds of GPUs, as noted in NVIDIA's report.

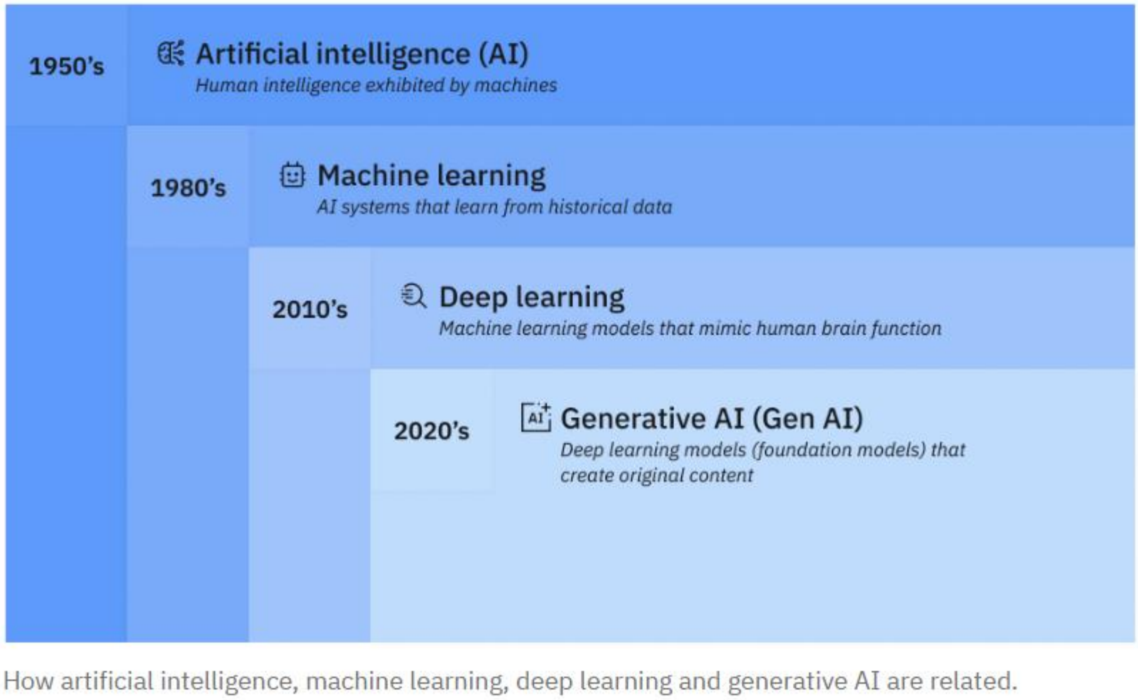


*Figure 2.20: How Artificial Intelligence, Machine Learning, Deep Learning and Generative AI are related (*Screenshotted *from IBM* website*, 2025).*

Therefore, the booming wave of AI is creating surging demand for high-performance chips. These chips, such as GPUs (Graphics Processing Units), TPUs (Tensor Processing Units), and FPGAs (Field-Programmable Gate Arrays), are critical for AI applications. This demand is evident across sectors like data centers, automotive (for Advanced Driver Assistance Systems - ADAS and autonomous vehicles), consumer electronics, and industrial applications, contributing a critical role of the semiconductor industry in enabling AI advancements. Conversely, the semiconductor industry will also experience advancements and increase efficiency in chip design and production by leveraging AI. The global artificial intelligence in semiconductor market size was USD 48.96 billion in 2023, accounted for USD 56.42 billion in 2024, and is expected to reach around USD 232.85 billion by 2034, expanding at a CAGR of 15.23% from 2024 to 2034 (PrecedenceResearch, 2024). It is a new source of growth for the economy globally and a new technology that powers a nation's sovereignty in the future.

With this technology, the EU is lagging behind in the race, with all the top generative AI tools in the US and China, none of which are in Europe. As the pace of AI innovation and development picks up, underpinned by advancements in big data and high-performance computing, the US and China are both at the forefront. Europe, meanwhile, despite having certain advantages such as a strong industrial base and leading AI research and talent, is punching far below its weight. This state of affairs is especially due to the fragmentation of the EU's digital market, difficulties in attracting human capital and external investment, and the lack of commercial competitiveness, according to Hasija et al.'s research (Hassija et al., 2020). Understanding this situation, the EU acted as a global leader in ethical and scalable AI through a dual strategy of robust regulatory oversight and unprecedented investment. The EU published the EU AI Act, the world's first comprehensive AI regulation, on July 12, 2024, under the digital strategy of the EU, aiming for trustworthy AI in Europe (EuropeanCommission, 2024a). Following the AI Act, Since February 2, 2025, the EU AI Act has banned eight categories of "unacceptable risk" AI systems, the highest risk level in 4 risk levels in the Act, including social scoring by public authorities, real-time biometric identification in public spaces (with narrow exemptions for counterterrorism), and AI that manipulates behavior through subliminal techniques or exploits vulnerabilities related to age/disability. Violators face fines up to €35 million or 7% of global revenue, whichever is higher. Early enforcement actions include a €12 million penalty against a German recruitment platform for deploying emotion recognition tools that discriminated against candidates with anxiety disorders. In the coming years, the regulation set a deadline for organizations to manage AI; in August 2025, general-purpose AI models (e.g., large language models) must comply with transparency requirements, including detailed training data summaries; in August 2026, high-risk AI systems in healthcare, transportation, and education require conformity assessments and human oversight protocols; and in August 2027, full implementation of post-market monitoring for all AI systems, according to the EU AI Act. In parallel, the EU government gives the extreme investment fund to mobilize €200 billion for AI sovereignty, which European Commission President Ursula von der Leyen announced at the AI Action Summit in Paris on February 11, 2025. This InvestAI initiative will boost European AI innovation, with an investment fund of €50 billion to support the development and application of AI , combined with a €150 billion private sector pledge, over the next five years (Science & Business, 2025). Also, according to the European Commission, the EU is making a strategic investment to build four AI gigafactories, with a budget of €20 billion, dedicated to training very large AI models. Each facility will have around 100,000 cutting-edge AI chips, around four times more than the AI factories currently being set up. Additionally, each member also joined the race for investing in AI; Germany and France each contributed over $1 billion (Stateofeuropeantech, 2024). This investment initiative compares with the US-announced Stargate initiative, mobilizing $500bn worth of investment (Reuters, 2025), and Chinese company DeepSeek disrupted the market with the launch of its R1 model, a seemingly more cost and energy-efficient rival to established US players. China's strategy, the New Generation Artificial Intelligence Development Plan, is aimed at developing China's AI capabilities and making it a global leader in AI by 2030 (ESCAP, 2018). Future global positions will be determined by the AI race, with nations that are slower to develop AI being left behind.

### 2.8.2 Quantum computing

On February 19, 2025, Microsoft introduced Majorana 1, a quantum chip powered by a topological core architecture and a significant material innovation: the topoconductor. This is a "breakthrough type of material that can observe and control Majorana particles to produce more reliable and scalable qubits, which are the building blocks for quantum computers" (Microsoft, 2025). A topological superconductor, or topoconductor, is a specialized material that produces a distinct topological state of matter, which is neither solid, liquid, nor gas. These qubits are faster, smaller, and digitally controlled, without compromises in existing qubit technologies, and offer enhanced stability. Microsoft is also building a comprehensive quantum ecosystem, partnering with Quantinuum and Atom Computing to drive breakthroughs with existing qubits, notably the first reliable quantum computer. These collaborations support quantum skill development and hybrid application creation, crucial as AI and quantum computing integrate. Azure Quantum offers a unified platform for customers to access AI, high-performance computing, and quantum resources. Microsoft's Majorana 1 technology aims to accelerate the development of million-qubit quantum computers, moving the timeline from decades to years, according to Microsoft.

Quantum chips are used to make quantum computers, which are the technology that will "change the game" in the market. The quantum computer has just started developing and has a small market size, with the global market reaching $5.3 billion by 2029, growing at a CARG of 32.7% from 2024 to 2029; with more than 360 startups among over 13,000 companies, and about 1 million people worldwide contributing to the sector's global expansion (StartUs-Insights, 2025). Today, there are 5 key innovation hubs in the world to focus on quantum computing; they are BlueQubit (US), Quool (Denmark), QC Design (Germany), TreQ (UK), and SuperQ (India). Key players in this sector are IBM, Microsoft, and Google, which have invested $1.2 billion in photonic quantum computing and startups located in quantum innovation hubs, as mentioned above. One of the trends that quantum chips create is Superconducting Quantum Computing, which focuses on advanced quantum processors using superconducting circuits. The sector comprises over 25 companies, employing 1200 professionals and adding 180 new employees by 2024. The annual growth rate of 26.89% reflects interest from academic and commercial sectors that are developing stable and efficient quantum systems. The European quantum computing market is dominant in 2024, with 33.8% (GrandViewResearch, 2025). The technical complexity of quantum computing, requiring deep physics and engineering knowledge, fosters strong industry-academia partnerships. These collaborations are crucial for accelerating the development of cutting-edge quantum technologies and applications. Many European quantum computing firms work closely with universities to develop advanced quantum algorithms and software.

The most valuable quality of a quantum computer is its ability to perform large-scale simulations. This property accounts for a large number of applications in various kinds of industries (Hassija et al., 2020). With promising potential applications and benefits for many aspects of technology (i.e provide improvements to machine learning…), industrial goods (i.e logistics optimization, manufacturing chips with efficient circuit designs…), pharmaceuticals (i.e faster drug discovery…), materials (i.e molecule simulation for materials design), finance (i.e market simulation for better prediction of stock values) and R&D in Physics (implementation of various applications under condensed matter physics) (Hassija et al., 2020). This will be leveraging semiconductor technology in the current stage and requiring a new knowledge base to set a new technology development and market growth for the innovative hub, focusing on the future. Owning this new technology can bring to the nation's owner the new power of technology sovereignty and the advantages for developing innovation and economic perspectives. It may become a new power tool for the country owning this technology, like its own semiconductor technology.

# CHAPTER 3: METHODOLOGY RESEARCH

This chapter presents the research methodology adopted to investigate the research question, "*How can Open Innovation Ecosystems help Europe navigate geopolitical challenges and secure a strategically significant role in the global semiconductor market?".* Following Yin's qualitative research guideline book (2015 edition), the methodology emphasizes practical, inductive, and adaptive approaches to qualitative research. This chapter includes research design and approach, sample strategy, data collection and analysis, ethical considerations, and measures to ensure the quality and reliability of the findings.

## 3.1 Research Design and Approach

The choice of research design provides a framework for the collection and analysis of data (Bell et al., 2022). The research design in this research is qualitative research, which is appropriate when seeking an in-depth understanding of complex phenomena in real-world settings (Yin, 2015). Semiconductors are a high-tech category, considered the most complex industry and are one of the most important sectors for nations nowadays. Therefore, a qualitative approach allows for exploring nuances and perspectives that quantitative methods may overlook. To gain valuable insights and diverse perspectives on this topic, conducting in-depth interviews with high-profile professionals related to this field is crucial to understanding the industry and properly answering this research's research question.

## 3.2 Sample strategy

This research utilises a multiple-case study design, which, according to Yin's note (Yin, 2015), is ideal for exploring a phenomenon within its real-world context using multiple sources of evidence. Each interviewee represents a separate case and a perspective view from one of the three main parties in the Triple Helix theory (Etzkowitz & Leydesdorff, 2000) , allowing for both within-case and cross-case analysis to identify patterns and variations (Yin, 2015). The use of multiple cases enhances the robustness and generalizability of the findings (Yin, 2015).

## 3.3 Case selection

### 3.3.1 Purposes of case selection

Following Yin's (2015) advice on purposeful sampling, participants were selected based on their expertise and experience relevant to the research question. They represent three main sectors in the relationship between Government, Industry, and Academia. Government consultants will share their views and advice on innovation and technology policy. Industry experts who work as managers or higher in the top semiconductor companies provide real current practices and updated market insights. Professors and PhD with a research focus on Open Innovation theory and implementation in Business and Research will provide an overview, trusted theoretical knowledge and also the best-case studies in the semiconductor industry.

### 3.3.2 Interviewee profiles

They are one professionals who work as consultants for the government who make the regulations and policies, a high-network person in Europe, two Professors who work in Acamedia and teach Open Innovation Application in Business and Research and also apply this theory in their research; they are working in the top universities and living in Belgium where is the central of the EU; four professionals who work in the top companies in the semiconductor industry and they come from different key countries which this research focuses on the EU, US, China and Vietnam.

To maintain anonymity, each participant is assigned a code (see the table below). This is consistent with Yin's (2015) recommendation to protect participant identities while providing sufficient detail about their roles and expertise.

| **ID Code** | **Sector** | **Role/ Expertise** | **Region** | **Interview date** |
|---|---|---|---|---|
| G1 | Government | Policy consultants for the EU and other nations, business consultants, EU technology strategy, and a former business development manager to connect businesses and researchers in academia. | Europe | 26/03/2025 |
| A1 | Acamedia | Professor, Open Innovation, Digital Transformation, Academic Director | Europe | 27/03/2025 |
| A2 | Acamedia | Professor, Innovation strategy, industry-science links, technology markets, Economics of science & education; Innovative entrepreneurship | Europe | 01/04/2025 |
| I1 | Industry | Senior Architect, Design Chips Company | US | 06/04/2025 |
| I2 | Industry | Senior Sourcing Manager, using microchips for their applications | China | 08/04/2025 |
| I3 | Industry | Commercial Lead, Design Chips Company | Company based in the US, working based in Vietnam | 07/04/2025 |
| I4 | Industry | PhD and researcher in Electrical and Computer Engineering, using microchips for research in Wireless, 5G technology, and other technologies; experience in a project funded by the European Union's EU Framework Program for Research and Innovation Horizon. | Europe | 07/04/2025 |

*Table 4: Qualitative 1-1 Interview Calendar*

## 3.4 Data collection

### 3.4.1 Interview design

Semi-structured interviews are conducted with seven professionals to give flexibility to each participant to share probes and deeper insights. There is original research (Yin, 2015) to collect real insights instead of searching for bias by the researcher. A semi-structured interview differs from a structured interview because the interview guide does not have to be followed strictly, meaning that other questions can occur during the interview, depending on the interviewee's answers.

This research has seven experts related to the semiconductor industry and the Open Innovation theory. Although the size of interviewees is small, the profiles of the participants are rich, and they have extensive experience in their fields. They also have a wide network, which helps them have broader views when they share their insights.

### 3.4.2 Interview protocol

The research questionnaire is open-ended questions which cover the main sections: their experience related to semiconductors, geopolitical challenges in this industry and specific for Europe in the global context, how OIE helps the EU navigate the challenges and the opportunities for the EU to make this sector stronger in terms of collaboration, investment (focus on FDI) and capturing new technologies.

Before the interviews, I conducted extensive background research on the interviewees in order to frame the specific questions about their expertise and experience in the semiconductors industry, including policy consultants, especially in technology and innovation regulations and policies, Professors working on Open Innovation and Implementation this theory into Business and Research, and experts working in top semiconductor companies and using microchips in their applications as well. I try to have diversified expert candidates who come from the leading semiconductor markets, such as the US, China, and Europe and also come from emerging markets like Vietnam.

The research was conducted through a one-hour to two-hour interview in a hybrid format, with one interview in person and six interviews done through online meetings using the online meeting tools Google Meet and Microsoft Teams. All interviews have been recorded and transcribed in the document, which is allowed by the interviewees. It is also aligned with the nondisclosure, kept confidential, and used only for this master's thesis subject.

### 3.4.3 Data analysis

The study started with extensive literature research regarding semiconductors in the global context; the two best practice nations are the US and China, and the four leading European countries are in this industry. The literature was then divided into two main categories. The first one has a holistic view of the global semiconductor supply chain and how geopolitical challenges are critical for the EU in managing its market. This is called a geopolitical challenge for the EU in the global context of semiconductors. The second category explores how an OIEs is implemented in the industry and its best practices. This category was named the OIEs, which helps the EU navigate and strengthen its position in Semiconductors.

After the data from in-depth interviews had been collected and analysed, the insights and perspectives came from three main parties: the government, industry, and academia. The main topics shared are related to how geopolitical challenges impact microchips in the EU, how OIE implementation is in this category, and how the EU can navigate the challenges and capture the opportunities in this field. Each interviewee has extensive experience and a vast network in the field, which helps to understand the clear perspectives and strong evidence to understand more about the challenges and opportunities for the semiconductor industry in the EU.

The analysis process was followed by Yin's guidelines in his qualitative research book (2015), involving the inactive process of data disassembly, coding, pattern identification, interpretation and conclusion.

### 3.4.4 Data analysis techniques

I use Yin's guidelines to analyze the data for this research, using a pattern-matching technique to map and compare the real-case practices with theoretical propositions from the literature; explanation building by developing a narrative explanation of how OIE can help Europe address geopolitical challenges, refined through iterative analysis, and combined with triangulation to corroborate findings across different data sources (interviews and documents) to strengthen the validity of the interpretations (Yin, 2015).

## 3.5 Method discussion

This section introduces the research method used, and its potential impact on the research conducted will be discussed.

Firstly, the existing literature covers the critical challenges of geopolitical issues in the semiconductor industry, especially after the COVID-19 pandemic, which created the global chip supply chain crisis and impacted Europe heavily. However, geopolitical challenges are increasing and becoming more important in this sector ever due to the link with technology sovereignty. It impacts the stability of the chip's global supply chain and the less dependent nations on outside technology, which the nations cannot control and be a threat to depend on a foreign power. This research gives fresh and updated views of experts from diverse backgrounds to understand how geopolitical challenges affect semiconductors nowadays.

Secondly, the Open Innovation Implementation Framework for the semiconductor industry in different regions of the world economy. Therefore, there needs to be a diverse view from the three main parties in the market to know how this concept works in reality and different contexts within the microchip industry. They are included in industry, academia, and the collaboration between the nation's strategy and policy.

The data collection from the interviews is considered to be rich and diverse. The reason for this is that the interview guides were developed after an intensive literature study. However, to make the data richer and updated, it can bring insights into actionable decisions and be valuable to be considered in the current global context; the research could be complemented with in-depth interviews with high-profile experts in three main areas: policymakers or consultants for government, both experts work in the top supply microchip and buyer chips companies, and academia in the Open Innovation Theory and Applications. Thus, the researcher believes that having a deep conversation with the experts on a particular topic under the current global tension context helps to see the research question clearly, more structured and in a real-life setting to make this research contribute more to the field.

These reasons help this research ensure the quality of the study following 4 criteria in Yin's notes which need to be constructed validity through multiple sources of evidence link the research question, data and conclusions, internal validity by matching pattern and explanation building to reduce risk of counterfeit interpretations, external validity by enhancing multiple cases, allowing to have general comparison for similar context and reliability which address through the development of a case protocol and the systematic documentation of all research procedures**.**

### 3.6 Limitations

Although the sample of interviewees is small, only seven profiles will limit the generalization of findings. Furthermore, reliance on self-reported data may introduce bias. The case study is missing from the European semiconductor company, which may limit insights from the industry sector. However, these limitations are mitigated by using multiple sources of evidence and rigorous analytical techniques.

# CHAPTER 4: FINDINGS

This chapter presents the findings derived from semi-structured interviews with seven experts in government consultancy, academia and the semiconductor industry. The data is organized into key themes that emerged during thematic analysis, addressing the research question "*How can Open Innovation Ecosystems help Europe navigate geopolitical challenges and secure a strategically significant role in the global semiconductor market?"*

## 4.1 Overview of data analysis

### 4.1.1 Analysis framework

I followed Yin's principles of data analysis (2015, Chapters 8 and 9), the analysis involved an iterative process of data disassembly, coding, pattern identification, and interpretation. This approach ensured that the findings were grounded in the data and supported by multiple sources of evidence.

### 4.1.2 Coding process

I used the Delve website tool to upload all seven interview transcripts and coded the key insights and information that interviewees shared in the interviews (see detailed coding in the Appendix). After coding, I identified key themes and patterns that link with the research question and theoretical concepts in the literature review. Key findings in this chapter are presented as the broader themes of the codes.

## 4.2 Key findings

### 4.2.1 Theme 1: Geopolitical challenges for European semiconductor sovereignty

**Description**

This theme highlights the shared perception among experts that Europe faces critical geopolitical challenges in the semiconductor industry, including supply chain vulnerability, minor impact on the research & development side, dependency on foreign technology, and increasing competition from China and the US.

**Supporting evidence**

The academic expert and the government consultant underlined, "If China moves into Taiwan, TSMC's factories are at risk…Europe should invite TSMC to build plants here for security and skill transfer."

The industry expert also shared that "TSMC controls a significant capacity to produce advanced chips, but they have many customers such as NVIDIA, Apple, Qualcomm…So, what if TSMC has an issue? It will break the whole supply chain."

However, other academic experts also emphasized the different impacts of geopolitical tensions on production and research. He shared, "For production, because there is no established position in production that Europe needs to protect. But it is very separate and different from the research side, where Europe and obviously also the US have a much stronger position than any other region. Europe is a hotspot of semiconductor research".

To address the lack of Europe's production capabilities, however, the government consultant pointed out that "Europe invests 2.2% in R&D vs. the US's 3%. We are lagging... and losing talent to Silicon Valley."

### 4.2.2 Theme 2: The role of Public – Industry - Academia collaboration to build a strong European semiconductor industry

**Description**

This theme illustrates the importance of collaboration between the public, industry, and academia under the Triple Helix model in fostering the European semiconductor industry. It shows the key roles of each party in the market.

**Supporting evidence**

The academic expert highlighted that "IMEC's partnerships with ASML or Intel show how OIEs bridge research and industry." These partnerships share research resources and collaborate between pre-competitive R&D labs and industry to make a unique product and advanced technology.

Furthermore, the government consultant also shared an exceptionally successful case study to collaborate with the university and industry to create maximum value for both academic and business. That is KU Leuven's business development center, which connects top researchers in labs with the market that needs to apply the research's results and bring the money back to researchers, the university, and reinvest the money earned back into the market, then by the time to build an economic region. He shared, "We formed four divisions: research collaboration, IP, spin-offs, and finance. All headed by brilliant people. Then we work with our company network, use our market insights and expertise in regulations and policies to make a deal and help researchers receive maximum benefits from their work."

The industry expert who works in Belgium also highlighted, "Working closely in a big collaboration between PhD and researchers from across Europe, like France, Belgium, England, Italy, Germany, and the top companies to solve the critical problem is a good chance to develop new technologies."

### 4.2.3 Theme 3: Challenges and barriers to effective OIEs implementation in Europe

**Description**

This theme shows the critical challenges and barriers that Europe is facing with ineffective OIEs applications. There are manufacturing chips' weaknesses and policy fragmentation.

**Supporting evidence**

The academic expert shared that during the COVID-19 pandemic, the car industry in Europe suffered a significant loss due to a lack of chips for producing new cars from Asia, mainly from China, Taiwan. He said, "Europe's car industry had a crisis during COVID due to chip shortages. Then Chinese car company filled the gap after that." Europe is too reliant on Asia's microchip supply chain. Missing the foundry part is also challenging when applying Europe's research to commercialize and strengthen the European semiconductor ecosystem.

Another academic expert pointed out, "GDPR stifles innovation, making innovation nearly impossible... While China adapts regulations as problems arise, Europe blocks progress with rigid frameworks." This shows the difference between China's and Europe's strategies for managing new technologies.

### 4.2.4 Theme 4: Policy recommendation for fostering OIEs in the EU semiconductor industry

**Description**

This theme presents policy recommendations from experts for making the OIEs in the EU semiconductor industry stronger. The recommendations come from the expert's experiences, observations, and case studies from the US and China.

**Supporting evidence**

The industry expert who works in the US shared, "Government subsidies are critical for fabs companies. But I think Europe lacks Intel-like champions like in the US".

Another industry expert who works in the Chinese market also shared, "I think building mature trust between partners in the collaboration is the most important, because it leads to the long-term vision and fosters innovation. It needs to start and lead from both Europe and China's governments to set up a strong foundation relationship first."

Furthermore, the academic expert claimed, "Pre-competitive R&D should stay open, with a wide network. They should collaborate with the US, China on early-stage tech to avoid inefficiencies and reverse engineering."

### 4.2.5 Theme 5: Talent and workforce development strategy

**Description**

This theme presents the key findings about building a workforce for semiconductors in Europe, which is one of the most important parts of getting strong and staying competitive in this technological sector.

**Supporting evidence**

The industry expert working as a PhD in this field shared that he chose Belgium and Europe to do a PhD because of "the respected culture, near my homeland, and job opportunities. So, I think attracting talents worldwide to come to Europe to study and stay to work here is the most important to fill the talent gap in the semiconductor industry".

The academic expert also shared that the challenge for Europe is that European students do not favour studying STEM, which is the most important knowledge base for technology faculty, and the STEM performance of European students is lower than other regions, especially Asia even though the school system has tried to promote it in at least a decade. Therefore, he suggested "…Skilled students or student immigrants…people come here to study, get a STEM degree, then tend to stick around for several years, and some stick around for 10 or 20 years. So, it is not that they all go back immediately, and this, I think, is a huge, underdeveloped opportunity for Europe".

The second academic expert also contributed to filling the talent gap strategy: "We need lifelong education for engineers. Sending software developers back to school for AI training to build talent pipelines."

### 4.2.6 Theme 6: Emerging AI and Quantum computing technologies' impact on the EU's semiconductors

**Description**

This theme highlights two emerging technologies, including AI and Quantum computing, which are important and linked closely to the semiconductor industry, and can reshape this technology in the future. This requires Europe to take a serious step into these technologies to capture them and gain the advantage of technology sovereignty for the region.

**Supporting evidence**

The academic expert shared that AI could accelerate semiconductors like we see in the current market; however, "we are still stuck on laptops and smartphones... IoT will require 10x or 40x more chips for sensors and intelligent machines". He also shared, "IoT and digital twins will disrupt industries... Europe should prioritize smart cities and healthcare applications." This can help Europe keep ahead of new technologies and be controlled by the region itself, reducing dependence on non-European suppliers.
Another academic expert said, "Quantum computing could disrupt classical semiconductors, in worst case... but Europe is unprepared." The industry expert who works in NVIDIA, US, shared the similarities: "Quantum computing is still in the research stage, and the biggest challenge is to get a stable system and commercialize it. But if it succeeds, it could change the entire landscape of the industry".

### 4.2.7 Theme 7: SMEs & Startups ecosystem

**Description**

This theme is unexpected findings, but it is valid for addressing this thesis research question. During the interviews, the experts shared common insights about the startups and SMES ecosystem that will support the semiconductor industry in Europe.

**Supporting evidence**

The industry expert who works in a US company based in Vietnam shared, "The biggest challenge for entering the semiconductor industry is very high entry barriers, especially money and talent". Therefore, establishing a semiconductor company requires comprehensive government and ecosystem support. It is hard to build a semiconductor start-up without getting strong support from the ecosystem, including public policy and regulations, the network industry, talent, and research and development from across the academic communities.

As the Chinese industry expert shared, "China has many major companies growing so fast now and driving innovation in the market, such as Tencent, Deepseek, Unitree Robotics…They started the companies as startups by getting support from the Chinese government through the policy and attracting top talent, and it is more important that the founders are still working there. They are strong leaders who take ownership to drive the company's growth in the long term." The policy and strategy from the government will support companies entering the hard technologies and solve critical problems in society. The strong leaders create an ownership culture, lead the companies to go long-term with the company, and create a network of new generation entrepreneurs, which helps the nation have a strong backbone startup ecosystem.

Regarding from startup to enterprise, the government consultant also shared the example of ARM semiconductor UK-base company, "Like ARM is an instruction set architecture software for computer processors, founded in Cambridgeshire, UK, created a new IP business model by licensing and was acquired by Softbank (Japanese company) with $32 billion in 2016 and is valued at more than $100B nowadays". This is a role model for a successful startup, and for scaling it with a unique idea, a talented team, and the right support, could make a lot of money. He also mentioned, "to set up the bio-tech economic region, we built bio-incubators... Location matters. If you do not house startups, they [startups] will leave." This is how to build a home for the startups, nurture them, and ultimately create an economic ecosystem. It could apply to any industry and can also apply to semiconductors.

## 4.3 Summary of findings

This chapter has presented the seven key findings from qualitative research by seven high-profile experts. There are six themes in the original research plan, and one new theme that was derived from the interview conversations. These findings contribute to answering how OIEs can help Europe navigate the geopolitical challenges and strengthen its semiconductor industry.

# CHAPTER 5: RESEARCH CONCLUSIONS AND CONTRIBUTIONS

This chapter concludes the study on *how OIEs can help Europe navigate geopolitical challenges and secure a strategically significant role in the global semiconductor market.* It synthesizes the main findings of the qualitative interviews, interprets their significance, and highlights the theoretical, empirical, and practical contributions. The implications for policy, practice, and theory are discussed in a final integrated conclusion.

## 5.1 Summary of key findings

This research identified seven key themes that will strengthen the future of the European semiconductor industry.

1. **Geopolitical challenges**: Europe faces significant geopolitical challenges in the production of semiconductors, particularly, including supply chain vulnerabilities, dependence on foreign technology, and increasing competition from China and the US. However, Europe is still leading the research with advanced labs and wise collaboration with worldwide research hubs like IMEC in Belgium.
2. **Public – Industry – Academia collaboration**: Building an effective and strong collaborative partnership among government, industry and academic institutions is critical to Europe's semiconductor industry. Each sector has its roles and contributions in building this industry. However, there is a need to reduce regulation fragmentation and foster collaboration between research institutions and businesses.
3. **Challenges and barriers to effective OIES implementation**: The significant challenges to effective OIES implementation in Europe are building the foundry competence and simplifying the regulatory systems to strengthen microchip technology competencies and foster commercialization through businesses, including all stages of business, from startups, SMEs, to enterprises and multinational companies.
4. **Policy recommendations**: Experts recommend government subsidies for establishing fabs manufacturers, in collaboration with the leading foundry company TSMC, to reduce dependence on the supply chain and promote knowledge transfer; building trusted partnerships with partners, especially with China, diversify partnerships to emerging market such as Vietnam; and staying open the pre-competitive R&D collaboration.
5. **Talent and workforce development**: Building a skilled workforce for semiconductors in Europe is essential, with strategies including attracting international talent, immigrant students and lifelong education.
6. **Emerging technologies impact**: Emerging technologies such as AI and quantum computing have the potential to reshape the semiconductor industry, requiring Europe to take proactive steps and strong moves.
7. **SMEs & Startups Ecosystem**: Startups and SMEs require comprehensive ecosystem support, including public policy, industry networks, and strong leadership. This new finding was found through the common sharing of experts in the interviews. This insight can provide a more precise answer to the research question and practical contributions to the European semiconductor ecosystem.

The European business environment is considered risk-averse compared to the US risk-taking environment. At the same time, China is led by state-owned companies and an extensive talent network that studied and worked for a while in foreign countries, especially in the US, and then returned to China and made a new wave of startups, strong leaders in innovation with the highest nationalist spirit.

## 5.2 Discussions

### 5.2.1 Interpretation of key findings

The study found that geopolitical challenges, such as supply chain vulnerabilities, dependence on foreign technology, and global competition, especially from the US and China, remain a central concern for the European semiconductor industry. These findings align with the recent literature emphasizing the strategic risks of relying on non-European suppliers. The interviews further revealed that the EU lags behind in microchip manufacturing capacity, even though the region is leading in research, which is raising concerns about European sovereignty in this advanced technology.

Collaboration between the public, industry, and academia showed that each party's role in the ecosystem is to support the industry's growth and become stronger. This aligns with the Triple Helix framework, which underlines the necessity of strong cross-party partnerships in the high-tech industry. However, the problem of regulatory fragmentation and an incoherent economic region network within Europe makes the collaboration not yet optimize the benefits of economic and political perspectives, as several interviewees highlighted.

The challenges and barriers to OIEs implementation in Europe were both structural and cultural. On the structural side, Europe has regulatory complexity and a lack of chip production capability, while on the cultural side, it is about risk-aversion. These things limit commercializing from the research part and scaling up the startups and SMEs. Europe lacks a trillion-dollar valuation company like NVIDIA in the US or disruptive startups such as Deepseek in China, which will affect the industry's innovation in the future. These findings extend prior research by showing that, in addition to the advanced technology factor, large-scale companies with strong R&D departments and a close connection with institutions play a vital role in fostering innovation.

### 5.2.2 Theoretical contributions

This research contributes to the literature on OIEs by highlighting the unique challenges and opportunities within European semiconductor industries. This research extends the OIES framework by integrating geopolitical risk factors. This dimension is still new and has not yet been fully explored in prior studies. Most research linking open innovation and geopolitical risks started around 2020, when the COVID-19 pandemic occurred and created a global supply chain crisis. Moreover, the term geopolitical in semiconductors also got attention worldwide when Trump became the US president for the first time in 2017, when his agenda started restricting exporting core technologies to China, especially products related to microchips.

The findings from this research are consistent with Leten’s research, which analyzed the case of IMEC, a leading European public research institute, to show how orchestrating innovation ecosystems, particularly through carefully designed IP models, helps to enable value sharing, risk reduction, and successful multi-party collaboration in nano-electronics (Leten et al., 2013). This shows that even though Europe's semiconductor research is strong, ecosystem orchestration, IP governance, and public-private partnership are essential for scaling innovation and commercialization. Additionally, Kuan & West (Kuan & West, 2023) discussed their research on how modularity and public R&D funding (e.g., Defense Advanced Research Projects Agency – DARPA - in the US) transformed the semiconductor ecosystem from vertically integrated oligopolies to competitive, open, and collaborative networks. This builds up the findings of this research, which suggest that government intervention and modular ecosystem design are crucial for Europe's semiconductor ambitions.

This research emphasizes the importance of addressing geopolitical risks, fostering mature partnerships with trusted and diversified partners, and creating supportive policies for SMEs and startups. Emerging technologies such as AI and quantum computing to set the semiconductor is not only about economic factors anymore, but also international political and national security factors. This research shared the current concern with applying the Open Innovation theory in the new geopolitical context in the critical industry, such as semiconductors. The Open Innovation framework fosters innovation, new technologies, and economic value for nations, businesses, and communities. However, it has also put the risks of leakage and dependence on foreign technologies.

This research also highlights the importance of the role of each sector in the Triple Helix model. This industry is advanced technology, requires complex knowledge and collaboration, and intensive investment, which cannot be done by any single sector in the market or in any single country to complete the whole supply chain for one single chip. Therefore, creating an effective collaboration between the Government, Business, and the University is essential for building success for the semiconductor industry. Every sector has roles and powers to contribute to building a strong ecosystem of semiconductors, and in Europe, in this case study. Strong collaboration among the three sectors requires each partnership to be solid. The relationship between government and business is strong, which will foster business innovation and increase competition for businesses by leveraging policies and subsidies. The sharp business and university partnership will encourage the application of new inventions and innovations to commercialization. Moreover, the government-university relationship is bold, which will help to build a unique and competitive labour pool for industry. Missing any part of those partnerships hinders the strengthening of advanced technology, such as semiconductors. The role of government in dealing with geopolitical risks is higher than before. However, it does not require a single action from policymakers; all sectors need to increase their attention and action to achieve a stronger and more active outcome than ever before and to optimize investment resources from all partners. There is a learning observation from the Chinese government to the government setting the ambitious goal in advanced technologies, including semiconductors, to drive the market's focus and delivery, but what is more important is still the effectiveness of collaboration rather than its form. These findings also align with the highlights from Huggins's research (Huggins et al., 2022) that Europe's fragmented innovation landscape requires cross-border, cross-sector collaboration to achieve critical mass and global competitiveness, and only strong Public–Industry–Academia collaboration can overcome Europe's scale and commercialization challenges.

However, these findings also show a dilemma for openness in innovation under the geopolitical tensions, which, in line with a highlight from Open Forum Europe, using open sources such as open hardware platform RISC-V or open foundries to help design semiconductors and build a capacity for this industry is a strategic lever for Europe, but global politics make it hard to balance this openness to maintain control and sovereignty (OpenForumEurope, 2022). This research shows that building a trusted and long-term partnership through open conversation and respect is the key to sustainable development and robust innovation in semiconductors, one of the new weapons in the contemporary world.

### 5.2.3 Practical contributions

This research contributes multiple actionable directions to the fields through interviews and case studies.

**For Government**

This research presents requirements for simplified regulation processes and increases investment budget in the European region scope, where the EU's R&D budget is currently 2.2%, compared with 3% in the US from the government sector. Reducing fragmentation in regulations and faster processing are key factors that help businesses put less pressure on paper documents, saving time and resources to invest in innovation and business. It also helps governments manage their policies and nations more efficiently, especially in the European Union region. Increasing investment through additional subsidies for the lack of semiconductor technology to attract more investment, especially FDI, such as a foundry, is essential for European semiconductors. The government also needs to create an environment to support the startups & SMEs, which is critical to get a strong semiconductor ecosystem, by creating a semiconductor region located near the university and businesses, to foster networking, collaboration, knowledge transfer, and increase the commercialization of research works into the economy.

This research also suggests that creating a sustainable and competitive program to attract international students and immigration talent, such as a long-term VISA for STEM international students or providing support for students learning STEM in Europe, especially when the Trump's government policy for international students is raising strictly and less-open as currently, is needed to fill the workforce gap and become more advantageous in research and development in this category in the future.

**For Industry**

As discussed in chapter 2, there are four main phases of making one microchip: Research & Design, Manufacturing (Foundries), Assembly, Testing and Packaging (ATP), Distribution and Integration (Commercialization). Europe is in a strong position in the first phase of Research & Design, especially pre-competitive research, with much more focus on advanced technology in IMEC and other semiconductor research institutions in Germany, France, Netherlands, which should foster the outflow of knowledge by licensing, expanding research labs and exchanging and collaborating with new research hubs located in research hubs. However, manufacturing is Europe's lacking competence, which should take an inflow of knowledge, particularly from the leading players in this area, especially TSMC. TSMC also apply the Open Innovation framework in this company, creating the annual TSMC Open Innovation Platform (OIP) Ecosystem Forum to connect more than 750 partners in 6 regions in the semiconductor industry in 2024 (TSMC, 2024a) to foster innovation in producing advanced microchips.

The study shows that to have a leading innovation company, a strong leader is required. The expert shared that many case studies in China and the US, which are leading innovation streams, come from the new startups, the private companies, whose founders, such as Chinese companies Deepseek, Unitree Robotics or NVIDIA in the US, still lead. When a founder leads the company, it has a strong spirit consistent with the original mission and long-term vision. Whether investment in the company comes from, it will still be more ownership and a strong position to stay committed to innovation and long-term benefits for the company and employees.

The research also shows that increasing engagement and collaboration between business and research institutions and universities is the way to foster embeddedness and spillover of knowledge and intellectual property, which is needed to commercialize the innovation and scale up the startup faster.

**For Academia**

Based on the reality that the semiconductor talent shortage situation and the European students are not interested in STEM education which PISA Scores decreased over five years (see the data in table below), while continue investing STEM program to attract European student at young ages, having programs to attract international students and top talent to Europe and keeping them studying and working here in the long term is important for building a workforce for semiconductors in Europe.

| Country | Continent | Overall PISA Score 2022 | PISA Scores Math Score 2022 | PISA Scores Science Score 2022 | PISA Scores Reading Score 2022 | PISA Scores Overall Score 2018 | Rank change btw 2022 vs 2018 |
|---|---|---|---|---|---|---|---|
| Singapore | Asia | 1679 | 575 | 561 | 543 | 1669 | 10 |
| China | Asia | 1605 | 552 | 543 | 510 | 1736 | -131 |
| Japan | Asia | 1599 | 536 | 547 | 516 | 1560 | 39 |
| Taiwan | Asia | 1599 | 547 | 537 | 515 | | New in the list |
| South Korea | Asia | 1570 | 527 | 528 | 515 | 1559 | 11 |
| Hong Kong | Asia | 1560 | 540 | 520 | 500 | | New in the list |
| Estonia | Europe | 1547 | 510 | 526 | 511 | 1579 | -32 |
| Canada | Americas | 1519 | 497 | 515 | 507 | 1550 | -31 |
| Ireland | Europe | 1512 | 492 | 504 | 516 | 1514 | -2 |
| Switzerland | Europe | 1494 | 508 | 503 | 483 | 1494 | 0 |
| Australia | Australia | 1492 | 487 | 507 | 498 | 1497 | -5 |
| Finland | Europe | 1485 | 484 | 511 | 490 | 1549 | -64 |
| New Zealand | Australia | 1484 | 479 | 504 | 501 | 1508 | -24 |
| United Kingdom | Europe | 1483 | 489 | 500 | 494 | 1511 | -28 |
| Poland | Europe | 1477 | 489 | 499 | 489 | 1539 | -62 |
| Czech Republic | Europe | 1474 | 487 | 498 | 489 | 1486 | -12 |
| Denmark | Europe | 1472 | 489 | 494 | 489 | 1503 | -31 |
| United States | Americas | 1468 | 465 | 499 | 504 | 1485 | -17 |
| Sweden | Europe | 1463 | 482 | 494 | 487 | | New in the list |
| Belgium | Europe | 1459 | 489 | 491 | 479 | 1500 | -41 |

*Figure 5.1: Top 20 PISA Scores in 2022, adapted from World Population Review Data at https://worldpopulationreview.com/country-rankings/pisa-scores-by-country*

Regarding staying updated with emerging technologies such as AI, Europe should create lifelong learning courses to upgrade the current engineering workforce and make this technology accessible to everyone, including the public. This will help to enhance the skill sets for workforce development and promote demand for the market.

Staying open in research is also important to stay leading in this area, which is the most advantageous part of Europe. European universities also need to be active in creating a connection between research and the lab, with businesses, creating a startup environment by supporting incubators, and staying closely with businesses to encourage innovation in the market.

### 5.3 Conclusion

The findings in this research present actionable advice for policymakers and industry, with recommendations about simpler regulations, government subsidies and increased FDI attraction, better startup & SME access, stronger Public – Industry - Academia partnerships, and STEM talent programs. These steps are vital for Europe to navigate the geopolitical challenges and strengthen its semiconductor ecosystem in the current context.

In conclusion, this thesis advances the field by addressing theoretical gaps, providing diverse empirical insights, and offering practical guidance to policymakers, industrial and practitioners aiming to improve Europe's global semiconductor standing.

# CHAPTER 6: RESEARCH LIMITATIONS AND FUTURE PROSPECTS

This chapter illustrates the research's limitations and suggests promising directions for future research and semiconductor development in Europe.

## 6.1 Research limitations

This research has several limitations.

### 6.1.1 Sample size and scope

This research is based on a qualitative analysis of seven high-profile expert interviews from government consultants, industry and academia. While this approach provides rich, in-depth insights and diversification, the small sample size and focus on selected stakeholders may limit the generalizability of the findings to the broader European semiconductor ecosystem.

### 6.1.2 Qualitative methodology

Using a semi-structured interview allowed for gathering detailed viewpoints from the experts, but this methodology brought potential subjectivity into the data collection and analysis processes. Readers should note that the results are based on the specific experts chosen and may not fully represent the range of opinions across the semiconductor industry.

### 6.1.3 Geographic and sectoral focus

This research focuses on semiconductors in Europe in the current global context; it might overlook variations present within different EU countries or between large semiconductor companies and startups or SMEs in the field. This research also limits the view of industry experts in some of the most important European semiconductor companies, such as ASML or ARM. This may lead to a missing part of the real updated technology achievement, the new strategies of leading companies in dealing with geopolitical challenges, and the new emerging technologies context.

### 6.1.4 Geopolitical and technological landscape

The geopolitical and technological environment is rapidly evolving, and it links together not only from an economic perspective but also from a national and global security perspective. This made new policies such as the EU Chips Act, the EU AI Act, emerging technology AI and quantum computing, and the tariff problem in the current trading war may change and update quickly. Therefore, some of this research's conclusions and suggestions might require re-evaluation if the situation changes.

## 6.2 Future prospects and research directions

There are some promising directions for future research and development in this field.

### 6.2.1 Expanding the industry experts

Future research should include European semiconductor companies, including large, medium, SMEs and startups, which will provide a broader range of views and practical case studies. They should also expand to include industry experts from other leading semiconductor markets such as Japan, South Korea, and Taiwan, who will give a better understanding of the successful factors in these countries and may contribute valuable insights to European countries.

### 6.2.2 Quantitative and mixed-method approaches

Future research can combine quantitative and qualitative methods or conduct a quantitative study on a large sample to provide more detailed data to better understand the role of OIEs in the practical aspects of the industry. It could enhance the generalizability of future findings.

### 6.2.3 Exploring the new key factor within the EU region analysis

To bring more valuable information and understand Europe's semiconductor economy, future research can explore more knowledge factors, such as the investment landscape, cultural aspects in each EU member country, and how they are connected to foster the semiconductor industry within the region.

### 6.2.4 Deepening analysis of emerging technologies

Future investigations are needed into how AI, quantum computing and other new disruptive technologies will reshape the semiconductor value chain, innovation ecosystems, and policy frameworks in Europe.

### 6.2.5 Policy and ecosystem experimentation

Future work could evaluate the effectiveness of current EU regulations and policies for semiconductors, such as the EU Chips Act, AI Act, Europe Digital strategy…; provide a method to measure the effectiveness of collaboration between the government, the semiconductor industry and academia; and the STEM talent program as they are implemented, providing updated feedback for the policymakers and industry leaders.

## 6.3 Conclusion

This chapter acknowledges the research's limitations and presents promising directions for future research and industry development in Europe's semiconductor sector. The limitations are in sample size, qualitative methodology, selected and focused experts, and the evolving geopolitical and emerging technologies landscape, which show challenges to the generalizability and sustainability of the findings. However, this research provides a valuable foundation for understanding the gaps of the OIEs framework and applying it to the real setting in the context of strategic competition.

Future research should expand the industry expert interviewees in Europe and other leading semiconductor countries, incorporating qualitative data and combining qualitative and quantitative methods to enhance the insights and provide more actionable suggestions. Future investigations should analyse the differences in semiconductors among European members to understand European semiconductor ecosystems completely. Future work should involve new disruptive technologies, including updating AI, quantum computing and other technologies, to update the new semiconductor value chain. It may provide new forms to apply the Open Innovation framework in this industry. Additionally, future research should evaluate the impact of the suggested implementation from this research, including government policy, industry and workforce development.

Despite its limitations, the research offers actionable insights for policymakers, industry leaders, and academic institutions to strengthen Europe's semiconductor sector, increase its strategic independence, and adapt to the rapidly changing global environment. By addressing the identified limitations and pursuing the suggested future research will help Europe build a stronger, more innovative, and more independent semiconductor industry, contributing to its economic and technological leadership, and technology security.

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**APPENDIX**

**Coding interview content**

**Key themes identified:**

- Theme 1: Geopolitical challenges for European semiconductor sovereignty
- Theme 2: The role of Public – Industry - Academia collaboration to build a strong European semiconductor industry
- Theme 3: Challenges and barriers to effective OIEs implementation in Europe
- Theme 4: Policy recommendation for fostering OIEs in the EU semiconductor industry
- Theme 5: Talent and workforce development strategy
- Theme 6: Emerging AI and Quantum computing technologies' impact on the EU's semiconductors
- Theme 7 (New findings): SMEs & Startups

| Quotes | Codes (level 2) | Codes (level 1) | Interviewee | Why does this matter? |
|---|---|---|---|---|
| **Theme 1: Geopolitical challenges for European semiconductor sovereignty** | | | | |
| - "If China moves into Taiwan, TSMC's factories are at risk... Europe should invite TSMC to build plants here for security and skill transfer." | Geopolitical risks, strategic autonomy | Supply chain resilience | A1 | Taiwan's geopolitical risks to Europe's dependency on Asian manufacturing. Highlights the need for Europe to build local fabs (e.g., via subsidies) to mitigate disruptions and retain talent. |
| - "I think it's very different for production and research. For production, because there is no established position in production that Europe needs to protect. But it is very separate and different from | Geopolitical risks, strategic autonomy | Impact of geopolitical tension on Production & Research | A2 | Separately, the impact of geopolitical tension on the production side and the research side. |

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| the research side, where Europe and obviously also the US have a much stronger position than any other region. Europe is a hotspot of semiconductor research…So I do think that again, research tends to be less politicized than many other areas of economic life.” | | | | |
| - "Europe invests 2.2% in R&D vs. the U.S.’s 3%. We’re lagging... and losing talent to Silicon Valley." | R&D investment, regulatory fragmentation | Policy gaps | G1 | Underinvestment and fragmented regulations (e.g., GDPR) hinder innovation. Contrasts with China’s state-driven R&D model, urging EU-wide initiatives like the Chips Act. |
| - “TSMC controls a significant capacity to produce advanced chips, but they have many customers such as NVIDIA, Apple, Qualcomm…So, what if TSMC has an issue? It will break the whole supply chain” | Dependent on TSCM’s production | Supply chain dependency | I1 | Too dependent on one company and at risk of breaking the supply chain |
| **Theme 2: The role of Public – Industry - Academia collaboration to build a strong European semiconductor industry** | | | | |
| - "IMEC’s partnerships with ASML or Intel show how OIEs bridge research and industry." | OIEs, Pre-Competitive R&D | Collaborative R&D | A2 | OIEs like IMEC reduce duplication of effort and accelerate commercialization. Demonstrates Europe’s strength in pre-competitive research but highlights the need for stronger industry alignment. |

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| - "We formed four divisions: research collaboration, IP, spin-offs, finance. All headed by brilliant people. Then we work with our company network and use our market insights and expertise to make a deal and help researchers receive maximum benefits from their work." | Triple Helix, Spin-Offs | New institutional business development model | G1 | KU Leuven's model (research/IP/finance integration) is a blueprint for Europe to replicate. Emphasizes the need for specialized transfer offices to scale startups. |
| - "Working closely in a big collaboration between PhD and researchers from across Europe, like France, Belgium, England, Italy, Germany and the top companies to solve the critical problem is a good chance to develop new technologies." | Collaboration between academia and industry, Open Innovation | collaboration & partnerships between industry and academia | I4 | Creating a project requires an extensive collaboration between researchers and companies to solve critical problems/issues, which is the way to generate more innovation. |
| **Theme 3: Challenges and barriers to effective OIEs implementation in Europe** | | | | |
| - "Europe's car industry had a crisis during COVID due to chip shortages. Then Chinese car company filled the gap after that | Supply chain vulnerabilities, commercialization gaps | Manufacturing weakness | A2 | Reveals Europe's overreliance on Asian foundries. Connects to Theme 1 (geopolitics) and underscores the urgency of building EU production capacity. |
| - "GDPR stifles innovation, making innovation nearly impossible... While China adapts regulations as problems arise, Europe blocks progress with rigid frameworks." | Regulatory barriers, risk aversion | Policy fragmentation | A1 | Contrasts Europe's precautionary regulatory approach with China's adaptive model. GDPR's compliance costs deter startups, slowing AI/quantum innovation. |
| **Theme 4: Policy recommendation for fostering OIEs in the EU semiconductor industry** | | | | |

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| - "Government subsidies are critical for fabs... but Europe lacks Intel-like champions." | Strategic autonomy, Fab subsidies | Industrial Policy | I1 | Advocates for EU subsidies to attract "anchor" manufacturers (e.g., Intel) while warning against over-reliance on foreign firms. Links to Theme 1 (geopolitical risks). |
| - "Pre-competitive R&D should stay open, with a wide network. They should collaborate with the US, China on early-stage tech to avoid inefficiencies and reverse engineering." | Global collaboration, IP leakage risks | Open vs. Closed Innovation | A1 | Balances collaboration (to avoid inefficiencies) with IP protection. Recommends sector-specific OIEs (e.g., quantum computing) to pool EU resources. |
| - "I think building mature trust between partners in the collaboration is the most important, because it leads to the long-term vision and fosters innovation. It needs to start and lead from both Europe and China's governments to set up a strong foundation relationship first." | Trust, long-term vision, and collaboration | Foster innovation | I2 | Europe should be open to partnering more deeply and broadly with China to foster innovation and build a stronger semiconductor ecosystem, but it needs mature trust. |
| **Theme 5: Talent and workforce development strategy** | | | | |
| - "I chose to do a PhD and stay in Belgium because of the respected culture, near my homeland, and job opportunities. So, I think attracting talents worldwide to come to Europe to study and stay to work here is the most important to fill the talent gap in the semiconductor industry". | Skilled immigration, STEM education | Workforce development | I4 | Europe's ageing workforce and talent drain to Silicon Valley threaten competitiveness. Proposes visa reforms and industry-academia partnerships (e.g., PhD programs with IMEC). |

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| - "We need lifelong education for engineers... Send software developers back to school for AI training to build talent pipelines." | Lifelong learning, upskilling | Education reform | A1 | Connects talent gaps to emerging tech (AI/quantum). Recommends EU-funded training hubs to reskill workers for next-gen chip design. |
| - "…Skilled students or student immigrants…people come here to study, get a STEM degree, then tend to stick around for several years, and some stick around for 10 or 20 years. So, it's not that they all go back immediately, and this, I think, is a huge, underdeveloped opportunity for Europe" | Skilled immigration, STEM education | Workforce development | A2 | Overperformance of foreign STEM students vs European students is one of the reasons to see them as the most valuable workforce to fill the talent gap in this industry for Europe. |
| **Theme 6: Emerging AI and Quantum computing technologies' impact on the EU's semiconductors** | | | | |
| - "Quantum computing is very potentially disruptive semiconductors, in the worst case... but Europe is unprepared." | Quantum computing, R&D prioritization | Disruptive innovation | A2 | Quantum's potential to bypass CMOS tech threatens Europe's existing strengths. Urges funding for hybrid research (e.g., IMEC's quantum-classical projects). |
| - "We're still stuck on laptops and smartphones... IoT will require 10x 40x more chips for sensors and intelligent machines."<br>- "IoT and digital twins will disrupt industries... Europe must prioritize smart cities and healthcare applications." | AI, R&D prioritization | AI, IOT technology | A1 | Europe should invest in niche application markets based on its strengths, such as healthcare or strengthen its weaknesses, like building smart cities. |
| - Quantum computing is still in the research stage, and the biggest | Quantum computing, disruptive innovation | Quantum computing, disruptive innovation | I1 | Quantum computing is a disruptive technology; it may |

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| challenge is to get a stable system and make it commercial. But if it succeeds, it could change the entire landscape of the industry” | | | | change the entire ecosystem. Being ready and focused on R&D in this field is critical to capturing new technology, as no nation owns it yet. |
| **Theme 7: SMEs & Startups** | | | | |
| - “The biggest challenge for entering the semiconductor industry is very high entry barriers, especially money and talent” | SME Challenges, Venture Capital | Innovation Ecosystem | I3 | Highlights Europe’s risk-averse funding culture. Recommend EU-backed VC funds (e.g., EIC Accelerator) to support semiconductor startups. |
| - "Like ARM is an instruction set architecture software for computer processors, founded in Cambridgeshire, UK, created a new IP business model by licensing and was acquired by Softbank (Japanese company) with $32 billion in 2016 and is valued at more than $100B nowadays”.<br>- "To set up the economic region, we built incubators... Location matters. If you do not house startups, they [startups] will leave.”." | Startup Success, Scaling | Role models | G1 | An example of a deep-tech startup in the 1990s, which has become successful today. |
| - , “China has many major companies growing so fast now and driving innovation in the market, such as | Entrepreneur, Ownership, Long-term vision | Role models | I2 | Strong, owner-led innovation and committed, long-term investment drive rapid growth in some major |

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| Tencent, Deepseek, Unitree Robotics…They started the companies as startups by getting support from the Chinese government through the policy and attracting top talent, and it is more important that the founders are still working there. They are strong leaders who take ownership to drive the company's growth in the long term.” | | | | Chinese companies, contrasting with a more democratic approach and emphasizing dedicated investors with a long-term vision. |