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Semiconductor Industry in Italy: mapping and future developments

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Abstract

The aim of this paper is to provide a first mapping of the Italian semiconductor industry to understand its relevance respect to the global one, and its development in the country. The chip shortage the world has experienced since 2020-2021 has hit the everyday life of everyone because chips are a fundamental component of common things such as cars, computers, TVs but also of very important elements of the industrial environment as industrial machinery. The semiconductor value chain is a complex and global system where several countries and continents are involved with different relevance. Many countries in the last years have adopted initiatives to strengthen their semiconductor industries and make them more resilient and independent from third parties. The EU itself has adopted the European Chips Act, a proposal of the EU Commission that provides a series of measures European countries should take. Regarding Italy, to promote initiatives in this direction, it is important to define the structure of the Italian semiconductor value chain, the firms involved, their size and their distribution throughout the country, and the stages of the chain in which they participate. This is the main goal of the paper. Once pointed out the strengths and the weaknesses of the industry, the paper provides different initiatives that can contribute to reinforcement of the semiconductor sector in Italy.

Keywords: semiconductor, mapping, shortage, Italy, resilience, initiatives

Abstract in italiano

L'obiettivo di questo articolo è quello di fornire una prima mappatura dell'industria italiana dei semiconduttori per comprenderne la rilevanza rispetto a quella globale e il suo sviluppo nel Paese. La carenza di chip che il mondo ha sperimentato dal 2020-2021 ha colpito la vita quotidiana di tutti perché i chip sono una componente fondamentale di cose comuni come automobili, computer, TV ma anche di elementi molto importanti dell'ambiente industriale come i macchinari. La catena del valore dei semiconduttori è un sistema complesso e globale in cui diversi paesi e continenti sono coinvolti con diversa rilevanza. Molti paesi negli ultimi anni hanno adottato iniziative per rafforzare le loro industrie dei semiconduttori e renderle più resilienti e indipendenti da terze parti. La stessa UE ha adottato l'European Chips Act, una proposta della Commissione europea che prevede una serie di misure che i paesi europei dovrebbero adottare. Per quanto riguarda l'Italia, per promuovere iniziative in questa direzione, è importante definire la struttura della catena del valore dei semiconduttori italiani, le aziende coinvolte, le loro dimensioni e la loro distribuzione su tutto il territorio nazionale, e le fasi della catena a cui partecipano. Questo è l'obiettivo principale del documento. Una volta evidenziati i punti di forza e di debolezza del settore, il documento fornisce diverse iniziative che possono contribuire a rafforzare il settore dei semiconduttori in Italia.

Keywords: semiconduttori, mappatura, penuria, Italia, resilienza, iniziative

Contents

Introduction

Since 2021, the world is experiencing an ongoing global chip shortage that is affecting more than 169 industries according to Goldman Sachs (2021), determining a disruption of the GVCs of these industries, and thus their slowdown. Such a high number of industries affected by this shortage stems from the spread of semiconductor chips in many products and devices of our everyday life, from PCs and smartphones to toothbrushes and air conditioners. This is not a traditional shortage, caused by the fact that companies cannot make chips. The problem is that the demand of chips has exceeded supply, determining a gap between the two that in 2021 reaches the 15% [1]. Such growth in the demand for chips is mainly due to the digital revolution that characterized our economies in the last years, and the supply was not able to keep the pace up. The semiconductor industry has been always characterized by a sort of cyclicality, but the COVID-19 pandemic exacerbated the situation, influencing the critical point of the value chain [2]. Hence, we can say that the crisis seems less cyclical and more structural. The geographic localization is a very important factor that influences the value chain [2]. In particular, it determines a differentiation regarding the answers of firms and States to the crisis. In case of firms, the strategy refers to the acquisition of chipmakers or mergers with specialized companies, but also to the reshoring, so the reallocation of production in the domestic market to shorten the supply chain, enabling a better control of demand and offer [2]. Hence, manufacturing companies are expanding their production capacity to make closer the design phase with the production one. User companies, instead, are adopting a multi-supplier logic to avoid the lock-in phenomenon, or also a homemade logic to guarantee the supply in peak times [2]. Regarding the actions undertaken by governments, they supported the firms' initiatives through industrial policies to sustain production. Countries like South Korea, India and Japan have adopted in the last years many initiatives to support the semiconductor industry to be aligned with US and China [2].

The paper is a first attempt to analyse the Italian semiconductor industry, its role in the global semiconductor value chain, and to define the possible initiative that Italian government together with Europe could adopt to strengthen the sector and help it to growth in the future. The main questions this paper wants to answer are the following:

- What is the role of Italy in the global semiconductor value chain?
- How many Italian firms participate in the semiconductor value chain? And in which stages are active?

- What are the stages of the chain where the footprint of Italian companies is little or does not exist, representing a weakness point for the country?
- What can Italy, together with Europe, do to increase the relevance of the Italian semiconductor industry in the global one?

The following chapters will tackle these questions and try to give some answers to them.

This paper is structured in the following way: in Chapter 1 there is an overview of the global semiconductor industry and the consequences of the chip shortage, and then the literature review; in Chapter 2 there is the methodology; in Chapter 3 there is the analysis of the Italian semiconductor industry, and then there are the conclusions.

1 Chapter 1

This chapter consists of an overview of the chip shortage with its consequences, a description of the semiconductor global value chain, and the literature available regarding this fundamental industry.

1.1. Semiconductor crisis

The causes of this chip shortage are multiple, and all contributed with different degrees to the current situation. Some of them are related to past actions made by governments and the consequences occur now, other are related to casual and natural events. Below are mentioned the four main causes of this shortage according to experts [3] [4] [5]:

- COVID-19 pandemic;
- US-China trade war;
- Severe weather and fire in companies' plants;
- Across-the-board demand for processors.

The COVID-19 pandemic is probably the event of the century, an event that has changed completely citizens lives and affected dramatically the economy. But what are the effects of the pandemic on the semiconductor industry? In the first months of the 2020, with the outbreak of the COVID-19 all over the world, many governments imposed lockdowns in their countries and many companies shut down their facilities, leading to the freezing of production and the depletion of inventories. The automotive and the industrial sectors were badly hit by this global shut down [6]. Automotive companies were forced to reduce their demand for semiconductors due to the reduction of sales, further spiking the demand [4]. At the same time, due to lockdowns and the increased use of remote work and remote learning, the demand for consumer electronics skyrocketed, absorbing the excess of semiconductors in the market [7]. When the demand for cars raised in the second part of 2020 and at the beginning of 2021, carmakers were not able to source enough semiconductors, because the production could not keep up [8]. Another consequence of the pandemic regards silicon, a mineral used in the production of semiconductors. The cost of silicon increased because of the mass production of vaccines. Indeed, both the vials and the chips are produced with the same type of silicon [4].

The US-China trade war is an ongoing economic conflict between the two countries. It refers to the reciprocal setting of tariffs and other trade barriers on the countries' products, including chips. This trade war began under the Trump administration, because the President in his electoral program "Make America Great Again" identified China as a key competitor in the race to be the first world economy. U.S. accused China to use unfair trade practises and of intellectual property theft, contributing to the US-China trade deficit [5]. In September 2020, the American administration imposed restrictions on Semiconductor Manufacturing International Corporation (SMIC), one of the biggest semiconductor manufacturers in the world and a Chinese company, in order to make it harder for the company to sell to companies related to the U.S. [9]. But the situation is much more complex. Regarding semiconductors, U.S. and China are interdependent. China is an exporter of chips, but it also acquires sophisticated integrated circuits from other countries, including the U.S., to insert them into electronic products that China ships around the globe [9]. Hence, these restrictions entail consequences also for American companies that sell to SMIC or acquire from the Chinese firm. Companies buying from SMIC were forced to source chips elsewhere, and they found out that the alternative chipmakers were already at full capacity. Chinese companies like Huawei started to stockpile chips to avoid a stockout that could damage the industry in China. All these elements are part of the determinants of the current global chip shortage.

Another important factor impacting the semiconductor industry is the climate change. It is the cause of the extreme events that in the last years have hit the world. Extreme weather conditions have hit manufacturing facilities, determining their shut down. A severe winter storm in February 2021 in Texas leads to the closure of two plants in Austin owned by Samsung and NXP due to loss of electricity [10]. In 2021, Taiwan experienced one of the worst droughts in more than a century, causing a shortage of ultra-pure water used by chipmakers like TSMC to clean their factories and wafers [11]. Then there were fires at facilities in Japan and Germany that affected the production of chips and of the equipment used in their production [12].

The last factor mentioned is the across-the-board demand for processor. As technology has advanced, chipmakers have pushed into the design of much smaller chips with TSMC that develop 3nm chips. Some industrial sectors like the automotive or the home appliance ones make use of older technologies like the 40nm or 28nm design, but these are not the first choice for vendors that can sell smaller chips for more, hence no one is investing in more fabs to make more of older chips [6]. This mismatch between demand and supply in some industries lead to the slowdown of them with critical consequences on the supply of final products.

This chip shortage has affected different industries around the world. As mentioned at the beginning, 169 industries were hit by the shortage because of the massive extension of the usage of chips in our life. As can be seen below the effects are different according to the sector hit.

1.1.1. Automotive

The automotive is one of these critical industries, probably the sector that experiences the worst consequences of this shortage. The losses can be rooted back to some errors made at the outbreak of the pandemic. As reported before, the carmakers cancelled production orders and therefore chips orders: the production of passenger cars fell from 67.149 in 2019 to 55.834 in 2020 [13], assuming that other sectors would follow, but this does not happen because demand for chips for the home appliances and consumer electronics skyrocketed due to the adoption of remote working by companies and institutions, and of remote learning by schools. Then, when the demand for cars soared in 2021, automakers remained without chips for their cars. AlixPartners (2021) forecasted a loss of $210 billion for the automotive industry at the end of 2021, growing from the previous expectations, with the production of passenger cars that increased to 57.054 in 2021 [8], higher than the 2020 data but far behind the pre-pandemic data. By the end of July, at least 17 factories had either closed or slowed the production for the lack of chips [14]. The bad results of the automotive are due to the great dependence of the sector on chips. In the last years, cars have become more and more digital, and the level of technology is very high, in particular in electric cars. From the Infotainment and the ADAS to electric rear mirrors and sensors, the presence of chips has increased a lot, making chips fundamental in the production of a car. Hence, the global chips shortage had a big impact on this sector.

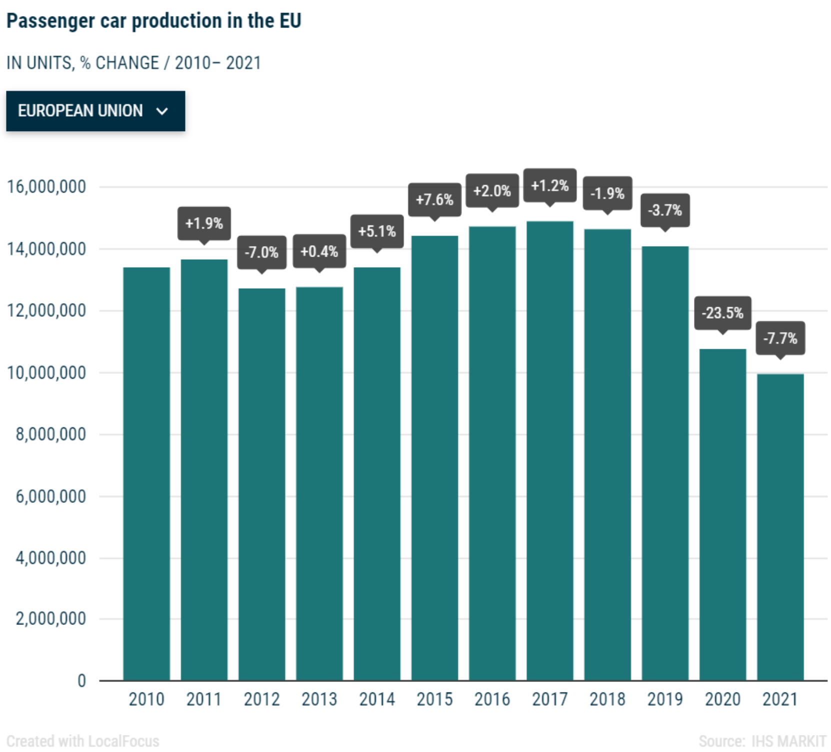

Figure 1.1: Passenger car production in EU

Source: ACEA, 2022

Here, it can be seen the data about the passenger car production in the European market. The slowdown started already in the last part of 2019, followed by the big fall in 2020 (-23.5%).

1.1.2. Consumer Electronics

The consumer electronics industry is one of the sectors affected by the shortage, but the effects are ambiguous. As said in the automotive parts, at the outbreak of the COVID-19 pandemic, the consumer electronics producers scooped the chips left unsold by the automotive industry up, because the demand for products like PCs and TVs was soared [8]. This growing demand stemmed from the initiative that governments implemented to fight the pandemic. Companies shut down their facilities and offices, institutions forced their employees to work from home, and schools closed, constraining students to learn from home. All these initiatives lead to a growth in the demand for consumers electronics products. But the demand was higher than the supply, that was reduced due to the shutdown of facilities, determining the lack of chips and raising prices. Within the sector, PCs and TV sets have grown much faster than smartphones, and this trend will persist in the next year [15]. In the 2019 the global consumer electronics market size was $729.11 billion with an expected reduction of 5.4% in 2020. In the 2020-2027 period, the market is projected to growth with a CAGR of 5.3%, from $689.45 billion in 2020 to $989.37 billion in 2027, due to the market's demand that will return to the pre-pandemic levels when the pandemic will be over [16].

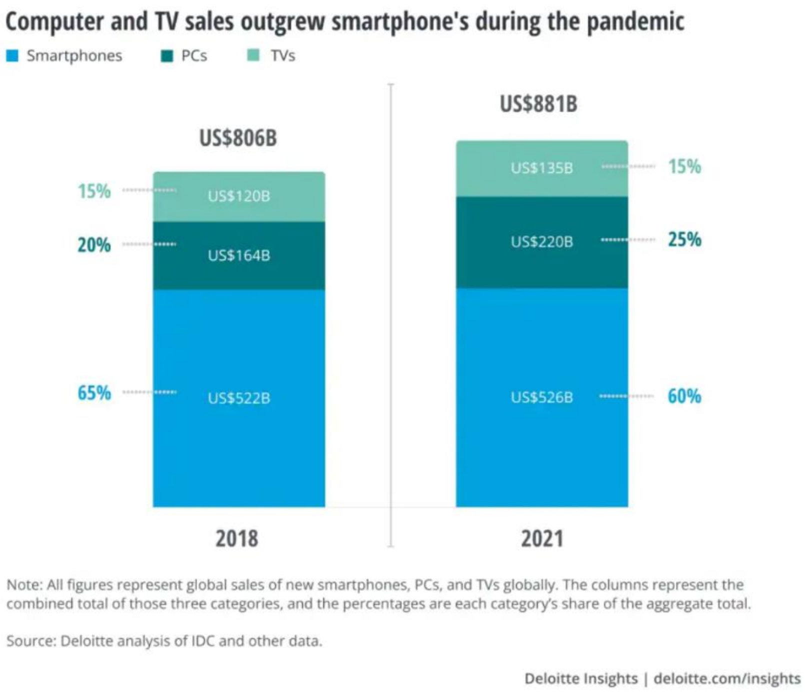

Figure 1.2: Computer, TV and smartphone sales during the pandemic

Source: Deloitte Insight, 2022

From this graph by Deloitte (2022), it is evident the growth of the sales of computers and TVs during the pandemic, even higher than the sales of smartphones in the same period.

1.1.3. Healthcare

Chips can be defined as the "brains" that power electronic and technological devices. Therefore, these little objects are considered crucial components of vital medical equipment and systems like ultrasound devices and defibrillators. During the pandemic, many devices critical in the treatment of the COVID-19 have chips as critical components. Semiconductor-rich devices have become more and more important in the last decades, also in the public health sector. They have been fundamental in the battle against COVID-19, but also in the treatment of other severe diseases like cancer, thanks to their capacity of gather and analyse data in real time, allowing for timely treatments. The medical semiconductor revenue in 2019 were $5.1 billion, hence 1% of the total semiconductor market [17]. So, this industry is not critical in the economic terms, but is crucial because it is related to the life of people. Many governments have recognized the semiconductor industry and its supply chain as "essential" for the purpose of the public health crisis. Indeed, the European Commission has issued a recommendation to Member States to address chip shortage and prioritize supplies to such important industry like the healthcare one [18]. The current shortage shows the potentiality of the semiconductors in this specific sector but could be also a threat because it can reduce the supply of chips for medical devices.

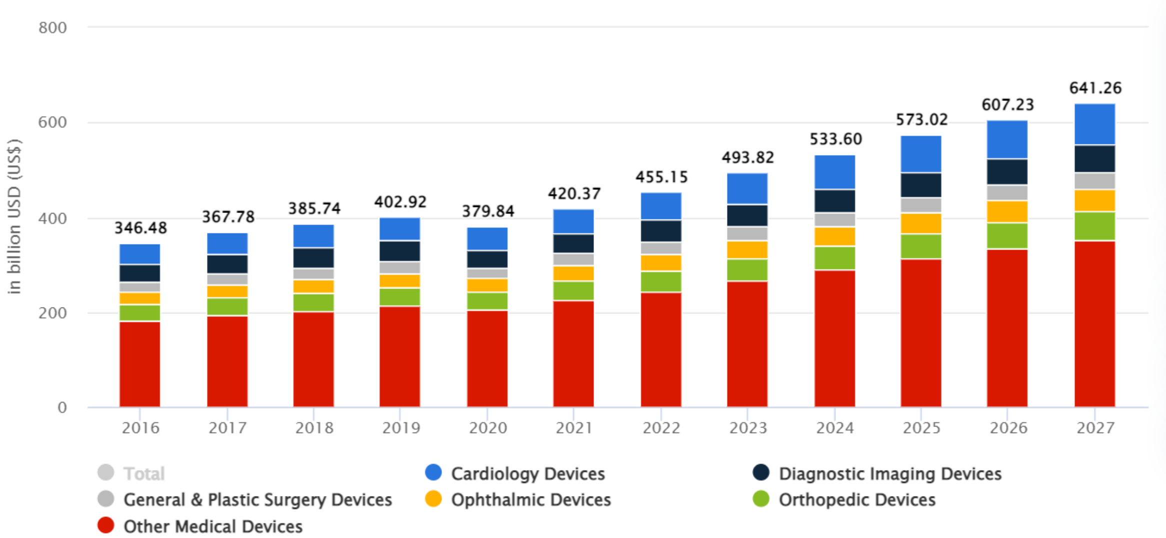

Figure 1.3: Medical devices sales

Source: Statista, 2022

In the graph above, it is highlighted the reduction of sales of medical devices in the 2020 due to the outbreak of the COVID-19 pandemic.

These are three examples of the industries affected by this shortage, probably the most visible ones, but as mentioned before, there are many sectors impacted like the defence and military sector or the home appliance one. Now the focus of the paper will be on the global semiconductor GVC and the role of Europe in it.

1.2. Semiconductor GVC

As mentioned before, chips are fundamental for the production of all electronic products, for the digital transformation and for many industries like the automotive, consumer electronics but also medical devices, space, defence and national security. Given the great importance attached to chips and the global chips shortage the world is experiencing since 2020-2021, many governments around the world are implementing initiatives to face potential future disruptions of the value chain. the attention will be on how the European Union is facing the current situation and what initiatives is implementing.

First, it is needed to understand what the role of Europe in the GVC of the semiconductor industry is. The semiconductor industry is characterized by four types of companies: Integrated Device Manufacturers (IDMs), fabless design firms, foundries and outsourced assembly and test companies (OSATs).

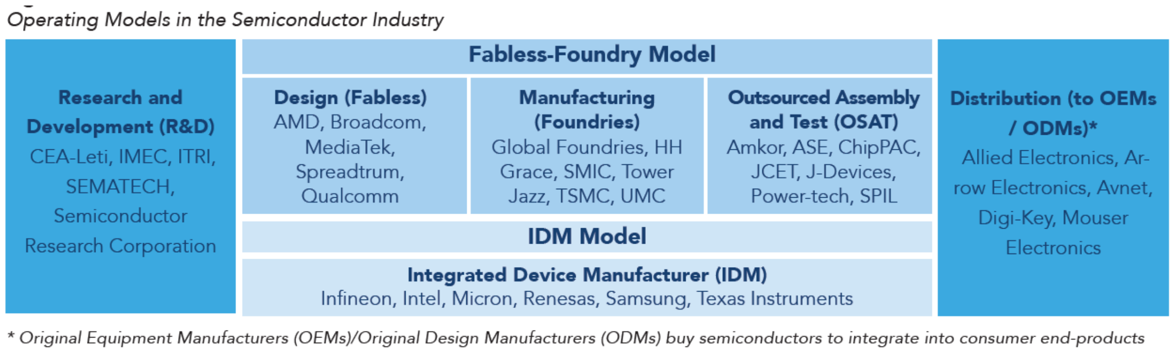

Figure 1.4: Business models in the semiconductor industry

Source: SIA, 2016, page 7

IDMs are companies vertically integrated across multiple stages of the value chain. It was the predominant business model at the beginning, but then the high investments in R&D and capital expenditures led to the emergence of fabless-foundry model. IDMs accounted for about the 70% of the global semiconductor sales in 2019 [1]. Fabless firms are companies specialized on the design stage, outsourcing the fabrication as well as the assembly and testing activities [1]. Fabless firms account for almost 30% in 2019. Instead, foundries are companies specialized in the manufacturing activities, addressing the needs of fabless firms and IDMs [1]. This specialization allows them to diversify the risk associated with large upfront capital expenditures required to build up the manufacturing capacity across a large number of design firms and IDMs. Currently foundries account for the 35% of total manufacturing capacity [1]. OSATs are companies that provide assembly, packaging and test services to fabless firms and IDMs.

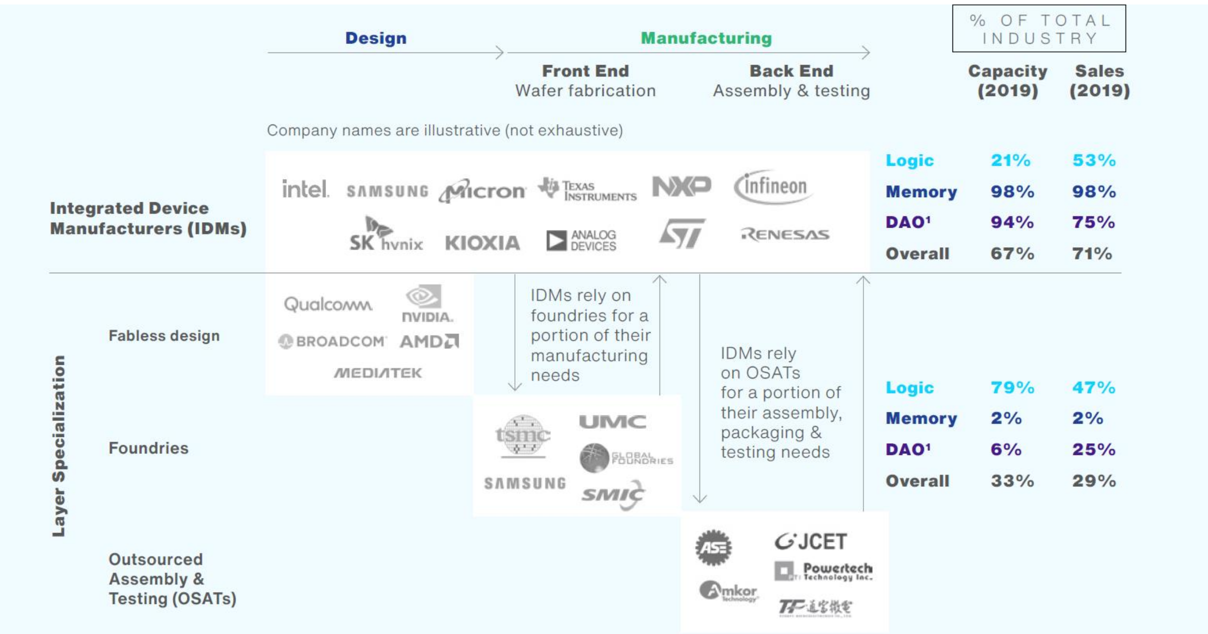

Figure 1.5: Example of companies per category of business model

Source: BCG, 2021, page 24

In the figure it is possible to see some examples of companies for every type of business model, and their capacity and sales in 2019. From the data, IDMs account for the 98% of memory chips sales and 75% of DAO sales. Instead, the layer specialization model accounts for the 47% of logic chips sales and 79% of logic chips production capacity.

The value chain of the semiconductor industry can be considered truly global because the six major regions (US, China, Europe, South Korea, Japan and Taiwan) each account 8% or more to the total value added [1]. The US is the global leader in the design of electronic devices, while China is the biggest manufacturing hub for electronic devices. Europe is the global leader in the automotive and industrial automation equipment. US, Europe, Japan and South Korea are really strong in the R&D activities, while China and Taiwan are leaders in the manufacturing and assembly and testing activities [1]. Regarding the fabrication of chips, Europe is one of the leaders in the production of Discretes, Analog, Optoelectronics and Sensors (DAO) and accounts for the 12% of the logic capacity of 10-22 nm chips [1].

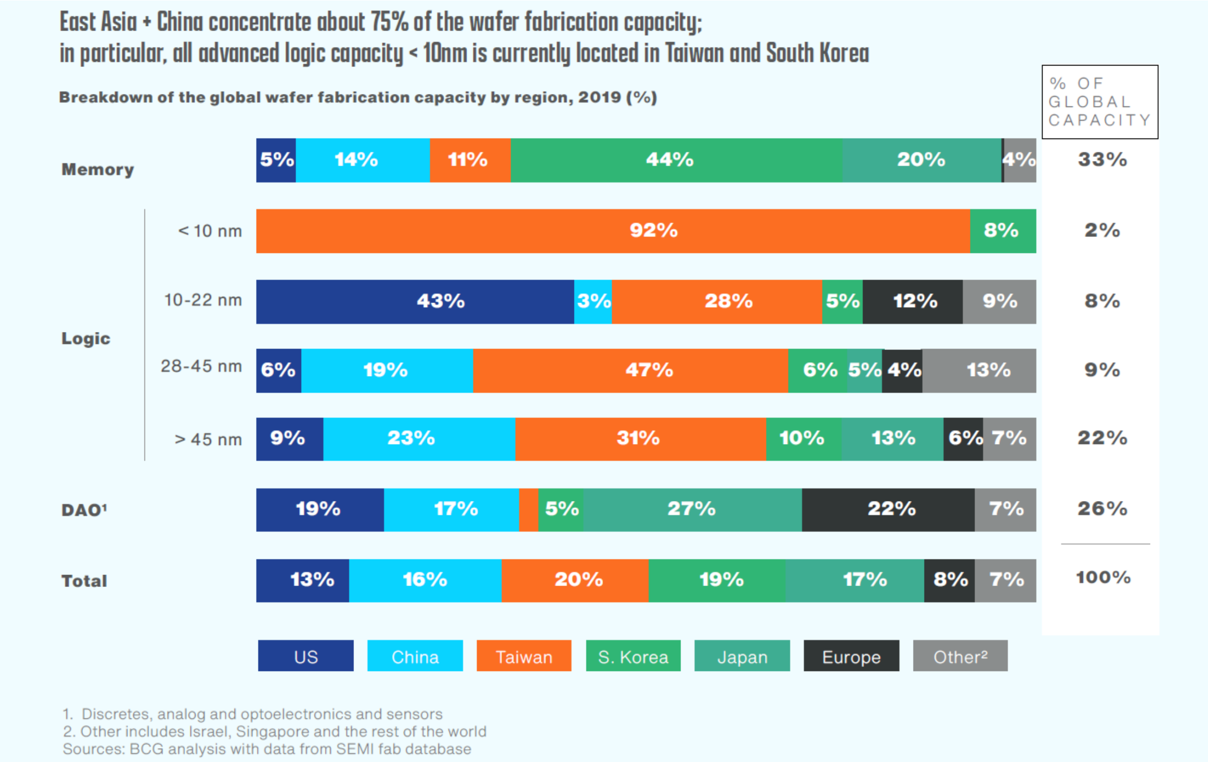

Figure 1.6: Breakdown of the global wafer fabrication capacity by region, 2019 (%)

Source: BCG, 2021, page 35

1.2.1. Europe's role in the GVC

Overall, Europe's global market share is around 9%. In order to double this value, the European Commission adopted on 8 February 2022 the European Chips Act, aiming at "reinforcing the semiconductor ecosystem in Europe, ensuring the resilience of the supply chain and reducing external dependencies". The initiative will be developed by following 5 strategic objectives:

1. Strengthening research and technological leadership;
2. Building and reinforcing Europe's capacity to innovate in the design, manufacturing and packaging of advanced chips;
3. Putting in place an adequate framework to increase production by 2030;
4. Addressing the skills shortage and attracting new talents;
5. Developing an in-depth understanding of global semiconductor supply chain.

To achieve these goals, the EU Commission will invest 43 billion euros into the semiconductor industry, transforming the region into an industrial leader around the world [6]. Although all the effort to become more independent, Europe needs the partnership with like-minded partners, like US [6]. The European Chips Act is composed of 3 parts:

- a Chips for Europe Initiative, to support large-scale technological capacity building and innovation in cutting-edge chips;
- a new framework to attract investments in production capacity and secure supply;
- a coordination mechanism between the Member States and the Commission to monitor market developments and anticipate crises.

The Chips for Europe Initiative aims at reinforcing the EU leadership and capabilities in the research field, fostering education, skills and talent in microelectronics, and supporting a network of competence centres across Europe [19]. The new framework allows the public support for the building of two new types of production facilities: "Open EU Foundries" that will produce mainly for other industrial players, and "Integrated Production Facilities" that will design and produce chips for their own markets [19]. The coordination mechanism is important for "strengthening the collaboration among Member States, estimate demand, anticipate crises and trigger the activation of the crisis stage" if needed [19].

From an analysis of the European semiconductor ecosystem by the EU Commission, it is stated that the role of EU is weaker than the role of its competitors. In particular, the development and production processes are concentrated in few countries like Italy, Germany, France and Ireland, and the ecosystem provide materials, equipment and services for the production of semiconductors. The main European firms supply OEMs of the automotive, industrial automation, security and healthcare industry, but also the defence, the telecommunication and the energy sectors [3]. Weaknesses of Europe in the semiconductor value chain are related to the design phase and the automation tools required as highlighted by the low number of firms producing IP cores and fabless firms [2]. The European semiconductor industry is leader in power electronics, sensors and advanced equipment for chip production.

The leadership of Europe in the automotive and industrial sectors of world economy has been highlighted before, and these sectors employ mainly less advanced chips (from 20nm to 180nm and beyond) and do not require the latest technologies. Hence, EU should focus on securing the supply for these industries. The EU has also some key players in the semiconductor industry, like ASML, a Dutch company that produces machines used by firms like TSMC, but also STMicroelectronics and NXP which are suppliers of Apple and other firms. The goal of the EU Commission, the 20% of the market share, is very ambitious because the EU does not have companies that manufacture the most advanced chips, and the EU players are manufacturing 22nm chips, so is unrealistic to think that they can catch up in a while. All these elements help to determine one of the areas of intervention of the European Chips Act, strengthen the stages of the value chain in which it is a leader (R&D, equipment and materials to run manufacturing plants) and secure the supply of the chips that are fundamental for the production of industries like the automotive and the industrial ones. Then Europe should develop the capabilities and the skills needed to design and produce the most advanced chips that are now the cutting-edge technology but also to develop the chips of tomorrow. This objective could be achieved attracting investments in innovative production facilities and develop a skilled workforce Regarding this particular point, many companies have announced in the last months investments in Europe. TSMC is planning to invest 10 billion euros in the region. The potential countries that will benefit are Germany or Italy [20]. The investment will create between 5000 and 3000 new jobs directly, without considering the jobs created through the suppliers. Intel has developed a $100 billion plan throughout Europe, of which 4.5 billion euros will target Italy [21]. The investment is related to the building up of an advanced plant for the second phase of production of chips, and it will set up 1500 jobs plus 3500 considering suppliers and partners. The investments will help also the adoption of newer technologies by the European industries raising their competitiveness. The ultimate goal of the initiative is not to become self-sufficient, which is impossible, but to "strengthen our strengths, develop new strengths and work with other countries in a supply chain where interdependences will remain strong" [19].

In this context, Italy has played an important role in the semiconductor industry in the last years. STMicroelectronics is a French-Italian company, and it is the largest European producers of chips with different facilities and offices in the Italian territory (Agrate Brianza and Catania). But there are highly specialized firms that belong to the different stages of the value chains, mainly in the equipment part. An example is LPE, a firm producing epitaxial reactors used to create silicon wafers, whose acquisition by the Chinese Shenzen Invetsment Holdings has been stopped by the Italian government through the Golden Power [22]. Then can be mentioned other companies like Meridionale Impianti (MI), Sapio, Spea, Memc Electronic Materials, and Technoprobe. All these firms are active in different stages of the value chain, from the design and installation of clean rooms to production of technical gases and testing machines. The Italian government is allocating 2.2 billion euros to support strategic supply chains, including semiconductors through a tool called Development Contracts, dedicated large-scale strategic and innovative productive investments programs [23].

1.3. Literature Review

After having talked about the global chip shortage and its consequences for the entire global economy, and the solutions adopted by some countries or regions, it is time to look at the mapping of the semiconductor global value chain and the literature related to this topic. To be able to apply the European Chips Act in the right way, European countries, including Italy, need to analyse their role in the GVC. This document is a first step in this direction. The focal point of this document is mapping Italian companies that participate in the semiconductor global value chain, to understand what are the stages of the chain in which the country is strong, and the stages in which the country is weak or even not present. This work is useful to look at the possible initiative that the Italian government and the European Union in general should take to strengthen the role of the region in the GVC, following the Chips Act. The main questions the paper aims to answer are:

- What is the role of Italy in the semiconductor global value chain?
- What are the Italian firms that participate in this global value chain, and in which stage of the chain are active?
- What are the stages of the chain where the footprint of Italian companies is little or does not exist, representing a weakness point for the country?

To answer these questions, it is important to look at the existing literature on semiconductor value chain to define the stages of the chain, the main countries that participate in it and their roles. For this purpose, two analyses made by the Boston Consulting Group (2021) and by the Semiconductor Industry Association (2016) were used about the structure of the value chain and a document by Yeung (2022) about the geographical shift of the semiconductor GVC toward East Asia and its growing importance as a central region for the sector.

The first step is the definition of the stages that form the value chain of the semiconductor industry. BCG (2021) argues that the semiconductor value chain consists of four main steps supported by a specialized ecosystem of suppliers that provide tools and equipment useful in the main steps. SIA (2016) adds the distribution activity to the four steps defined by BCG, but it is less relevant than the others. The four steps are pre-competitive research, chip design, wafer fabrication and assembly, packaging and testing [1]. For each activity, there are specific leader countries, and this leadership is given by the competitive advantage of the single country.

- Pre-competitive research: it identifies the materials and chemical processes to foster innovations in the other stages. It is basic research in science and engineering, and it is complementary to industry R&D [1]. Governments have a very important role because many major semiconductor technology breakthroughs were developed by government-sponsored programs [1]. This stage of the value chain requires enormous investments, and it is the reason why many firms develop agreements and alliances among them and with universities, research organizations, involving also governments [2]. The leader countries in this stage of the value chain are the US (13% of the total US semiconductor R&D in 2018), but in the last years China has invested a lot in pre-competitive research (5-6% of Chinese R&D spending in 2018) following its plan to build a strong Chinese semiconductor industry [1];
- Chip design: is the second stage, where companies design the ICs that enable the electronic devices to work. This activity is really knowledge- and skill-

intensive, hence the leader countries here are the US, Japan, South Korea and Europe [1];

- Wafer fabrication or front-end manufacturing: it is the first activity related to manufacturing, and it refers to the activities carried out to print the nanometre-scale integrated circuits. It is a very critical stage which requires highly specialized inputs and equipment [1] and it is characterized by high fixed costs and constant facility improvement to keep up with technological advantages [24]. In the semiconductor industry, the advances in the manufacturing process technology are called "nodes", that is referring to the size in nanometres of the transistor gates in the electronic circuits [1]. Up to now, the leading nodes are at 5 nanometres and are used for advanced logic and memory chips, while nodes above 180 nanometres are used for discrete, optoelectronics, sensors, and analog semiconductors [1]. Since fabrication requires high capital investment (30 to 40% of the annual revenues of firms), it is mainly concentrated in East Asia and mainland China [1];
- Assembly, packaging and testing or back-end manufacturing: in this stage chips are sliced from silicon wafers, and then are packaged and tested before shipping. This stage, as the previous one, requires significant investments in specialized facilities (15% of annual revenues of firms) [1]. As wafer fabrication, assembly, packaging and testing is primarily concentrated in Taiwan and mainland China, with new recent facilities in Southeast Asia [1].

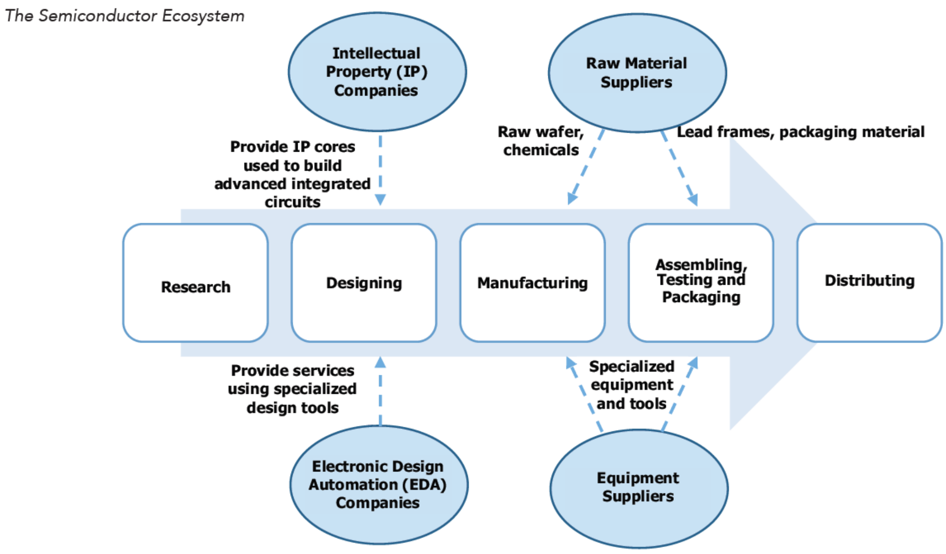

Figure 1.7: Semiconductor ecosystem

Source: SIA, 2016, page 6

Regarding the ecosystem that support the stages of the industry, they are essential for the production of semiconductors that are competitive in price, quality, performance and consumer preference [24]. There are IP companies that provide "IP cores", electronic device automation companies that provide tools for the design process, materials suppliers and equipment suppliers for the manufacturing process [24].

An important element not mentioned before is the rare earth elements (REE) and their location. The procurement and the extractions of minerals and rare earth elements is mainly related to China that has a strategic role in these activities [2]. The term "rare earth elements" refers to 17 elements of the periodic table that are crucial for the production of many products, from smartphones to photovoltaic panels. Two of them, gladius and indio, are the main elements for the production of chips [2]. In this market, China is the leader because it controls the 60% of the global reserves of rare earth elements and it refines the 80% of the global production [2]. Hence, it is possible to understand how US and Europe depend on the Chinese exports. This has also important geopolitical and economic consequences and influences the global competition for the frontier technologies.

Further considerations can be done about the role of East Asia. It has been highlighted that this region is particularly strong in the capital-intensive activities like manufacturing and assembly, packaging and testing. Yeung (2022) argues that East Asia is the global centre of gravity in the semiconductor GVC, particularly in ICs manufacturing (80% of worldwide IC fabrication capacity), and this perception is shared also by the documents analysed up to now. The geographical shift toward East Asia during the 2010s is related to the concentration of chip demand by device manufacturers in the ICT sector in the region, making it the most important market for electronic devices, supported by high investment by leading domestic semiconductor firms and by governments [25]. Two elements determine this pivoting: the massive demand for East Asian-made chips by intermediate customers, and the emergence of East Asia as the home region for the assembly of ICT devices and for new global lead firms in PCs and smartphones [25]. According to the author, the first element is related to customer intimacy, so spatial and high relational proximity through close customer-producer relationships, determining mutual dependency between the two [25]. The second element is based on the demand responsiveness in end markets [25]. When the companies producing PCs and smartphones started to locate their production facilities in East Asia, or outsource the production activities to East Asian countries, mainly China, many domestic companies started to participate in the semiconductor global value chain, specializing in the activities where they had competitive advantages such as wafer fabrication and assembly, testing and packaging. This phenomenon is related to the closer relationships between the new markets, requiring chips that are smaller, more efficient and more powerful, and the chip makers that need to satisfy these requests [25]. A similar phenomenon is visible in Europe.

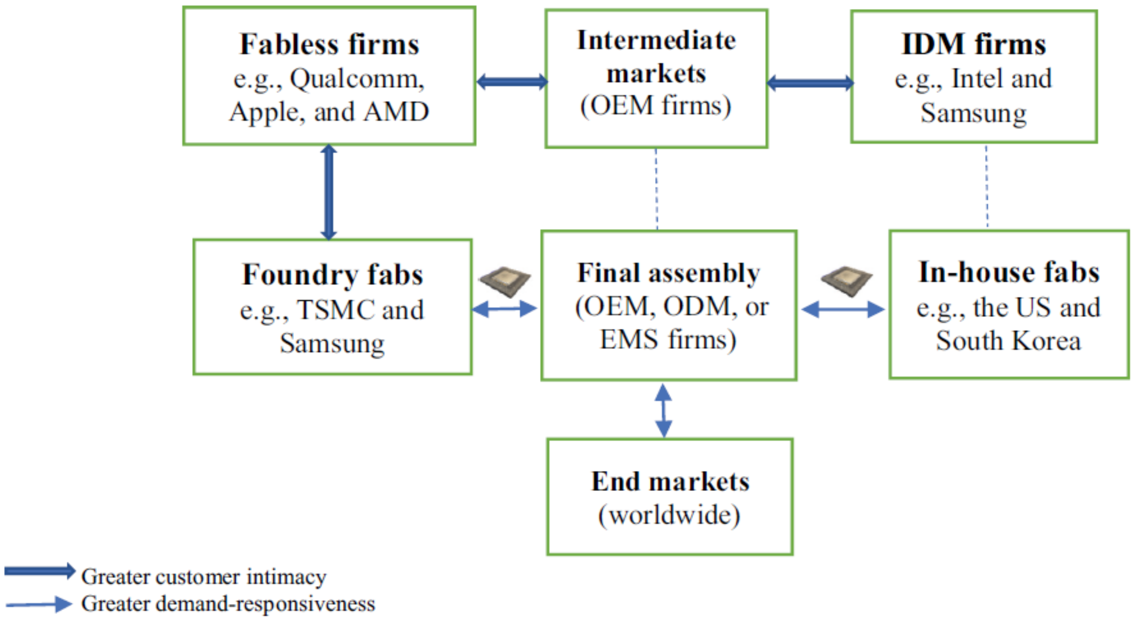

Figure 1.8: Market dynamics in semiconductor production networks

Source: Yeung, 2022, page 281

It is known that Europe is a leader continent for automotive and industrial equipment [1], and these sectors employ semiconductors above the 180 nm. Hence, semiconductors firms in Europe are specialized in the Discretes, Analog, Optoelectronics, and Sensors (DAO) [1]. Yeung (2022) argues that intimacy occurs between semiconductor firms and their OEM lead firm customers, or between foundry providers and their fabless customers. The geographical shift of electronic device makers toward East Asia was due also to the rise of this region as main market for these products. With almost 2 billion people, East Asia represented a very prosperous market where companies can expand their businesses. Hence, this enormous competitive pressure in the end markets worldwide led to greater demand responsiveness [25]. Such mechanisms could be leveraged in Europe to develop a strong semiconductor industry in the region. Since Europe is strong in the production of cars and in the industrial sectors like machines and equipment productions, chipmakers that manufactures the types of chips that are needed in these sectors could locate their facilities and their operations in Europe to gain from customer intimacy and demand responsiveness.

Thanks to the three documents used up to now, it was possible to understand the structure of the semiconductor value chain, the stages that form the chain, and the leader countries for each stage. The pivoting of semiconductor global value chain toward East Asia during the 2010s and the reasons behind it have been also analysed. Now, using the official proposal of the European Chips Act to the EU Parliament, the paper analyses what the EU Commission would like to put in place to strengthen the semiconductor industry in Europe. According to the document, the Union's overall global semiconductors market share is 10% in value, as confirmed by the BCG (2021). Europe is strong in materials and equipment manufacturing, but it is really dependent on other countries for design, manufacturing, packaging, testing and assembly of chips [19]. The plan of the EU Commission is that Europe should double its world production share to 20% in value by 2030, not only reducing dependencies to other countries, but also seizing the economic opportunities related to the growth of the market in the next years and increasing the competitiveness of the semiconductor ecosystem [19]. The ultimate goal of the Act is to jointly create a state-of-the-art European chip ecosystem that will include production [19], a stage of the value chain in which Europe is not strong and it is dependent on East Asian countries. The document argues that the objective is not to become self-sufficient, that is what China is trying to do although it is not an optimal solution [1], but is to "strengthen our strengths, develop new strengths and work with third countries in a supply chain where interdependencies will remain strong". The proposal consists of three main points:

1. Set up the Chips for Europe Initiative: it will enable the development and deployment of cutting-edge and next generation semiconductor and quantum technologies to reinforce advance design, system integration, chips production capabilities and skills [19]. This will be done creating an innovative design platform to reinforce Europe's design capacity, accessible on open, non-discriminatory and transparent terms for many stakeholders such as SMEs, start-ups and vertical sectors [19]. The creation of the "Chip Fund" will facilitate the access to debt financing and equity to support the development of a dynamic and resilient semiconductor ecosystem [19];
2. Create a framework to ensure security of supply: the aim is to attract investments and to improve production capacities in semiconductor manufacturing and advanced packaging, test, and assembly. The objective is to secure supply of semiconductors in the Union [19]. To do that, the Union could rely on two types of first-of-a-kind facilities, Integrated Production Facilities and Open EU Foundries. Integrated Production Facilities are facilities that are based on the IDM model, while the Open EU Foundries are based on the pure-play foundries used for wafer fabrication. The other objective of this point is the improvement of the resilience of the supply chains, establishing common standards and certification, common requirements for procurement [19];
3. Set up a coordination mechanism between the Member States and the Commission: the aim is to "monitor the supply of semiconductors, estimate demand, anticipate shortages, trigger the activation of a crisis stage and act through a dedicated toolbox of measures" [19];

The attention is placed over the first and second points, that are related to the strengthening of the value chain in the stages where Europe is less strong than other countries. The proposal is coherent with many programmes developed by the Commission in the last years such as the plan of EU Commission about the digital transformation of the Union by 2030 and the new industrial strategy [19].

The first point aims at filling a gap that Europe has in the research and innovation capacity respect to other countries. It has been already said that US and China are the leader countries in the pre-competitive research and in the innovation regarding technology [1] [24]. EU wants to catch up or at least to be closer to these countries supporting large-scale capacity building related to existing and cutting-edge and next generation semiconductor technologies. This initiative will increase the competitiveness and the resilience of the European semiconductor industry. The investments will be used to improve the design capacities of the industry, to set up pilot lines for preparing innovative production and testing and experimentation facilities around the region, to increase the capacities required for the developing of quantum chips, and also a "Chip Fund" for the access to capital by start-ups, scale-ups and SMEs [19]. This proposal is very important to reduce the dependence of European countries on third ones for innovation and the development of leading-edge chips and production processes, increasing the importance of the region in the semiconductor value chain. The second point is fundamental to reach a security of supply and to reinforce the resilience of the internal market. Integrated Production Facilities and Open EU Foundries are the elements that enable the EU to reach its goal. They are first-of-a-kind manufacturing facilities in the Union. Integrated Production Facilities are vertically integrated production facilities, so are similar to IDMs, and it is known that the main important IDMs are Intel (US) and Samsung (South Korea) [1] [24]. There are not so many IDMs firms in Europe, except for STMicroelectronics, the French-Italian company that produces sensors and chips for Nintendo, Apple and others. Hence, Integrated Production Facilities are meant to increase number of IDM model in the region. For Open EU Foundries the situation is much more difficult. It is well known that the leading country for foundries is Taiwan (90% of pure-play foundries is located there) [1]. Europe lacks completely of this type of business model, hence EU need to develop these capabilities from scratch. Open Eu Foundries are meant to offer a significant degree of their production capacity to other industrial players, like fabless semiconductor companies, developing semiconductor manufacturing in the Union. The building of foundries requires a lot of capital expenditures, both by companies and by institutions.

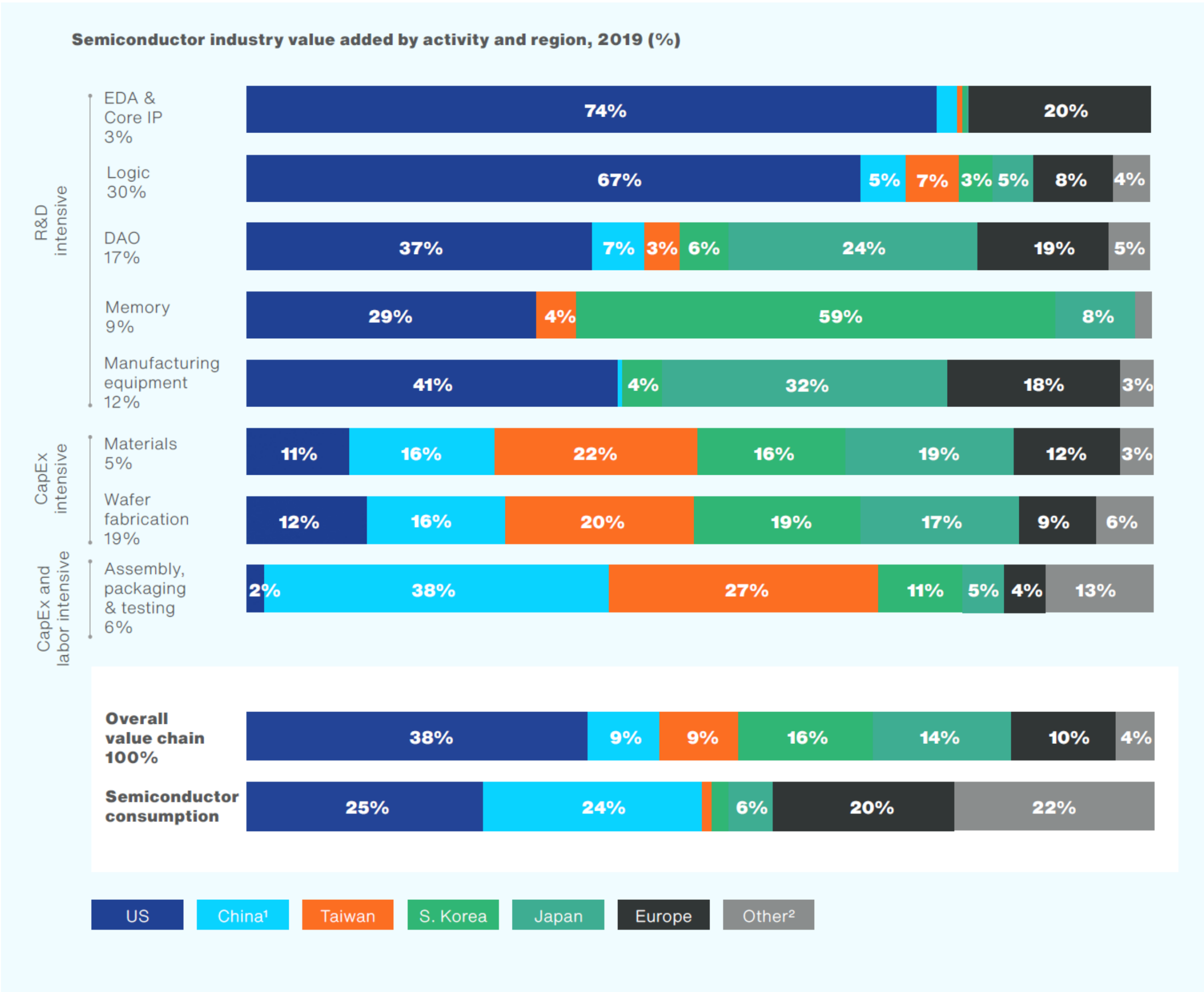

Figure 1.9: Semiconductor industry value added by activity and region, 2019 (%)

Source: BCG, 2021, page 31

It is interesting to see that Europe is responsible for the 20% of the semiconductor consumption, but it contributes only to the 10% of the value chain. This is why EU Commission wants to increase its share in the value chain through the Chips Act.

This is the proposal of the EU Commission to create a more important and resilient semiconductor supply chain in Europe. The analysis will be focused on the Italian semiconductor industry. The goal is to map the firms that belong to the semiconductor value chain to point out what are the stages in which Italian companies are missing and where the government could intervene following the European Chips Act, attracting investments or stimulating the creation of firms that can be active in those particular stage

2 Chapter 2

2.1. Methodology

The goal of this document is to map Italian companies that participate in the semiconductor value chain. In particular, the aim is to understand in which stage of the value chain they are active to identify what are the stages in which Italy is strong and weak or even absent. As mentioned, there are two types of sources that can be used: primary sources or secondary ones. This document is totally based on secondary sources due to the difficulty to get some primary sources like interviews with firms or managers of companies. The first step is the identification of these companies through a database called AIDA (Analisi Informatizzata delle Aziende Italiane) provided by Politecnico di Milano and Confindustria. To identify the firms, ATECO codes obtained in two ways were used. The first way is the conversion of US SIC codes provided by different document such as Duke (2016), a document about the growth of the semiconductor industry in the Philippines. The second way is the identification of ATECO codes of some Italian companies cited in some newspapers like La Repubblica (2021) or well-known companies such as STMicroelectronics. The second step is the analysis of the data provided by the AIDA database. For the research, the most interesting data are the number of employees, the location of the headquarters, the percentage of the budget invested in R&D, the name and the location of the Global Reference Shareholder of each firm. First, there is the classification of companies according to the number of the employees of the firm to see how many micro, small, medium and large firms exist in Italy. Then, the disaggregation of data according to the location of companies to see their distribution throughout the country. To structure the analysis in the right way, the framework developed by Gereffi and Fernandez-Stark (2016) for the analysis of global value chain was used. In their document, the two authors define 6 steps of analysis: Input-Output structure, Geographical Scope, Governance, Upgrading, Local Institutional Context, and Stakeholders Analysis. For the analysis, different documents like BCG (2021), SIA (2016) and Astrid (2022), the proposal of the EU Commission for the European Chips Act and the data gathered through the database AIDA were used to base the entire reasoning. These documents are useful in retrieving and describing all the elements related to the six sections of the analysis.

3 Chapter 3

This chapter consists of the analysis of the Italian semiconductor value chain with the mapping of the industry.

3.1. Analysis

3.1.1. Input-Output Structure

Following the Gereffi and Fernandez-Stark (2016) framework to analyse GVCs, it is possible to start with the input-output structure. A chain is the process that transform inputs in outputs that then go in the hand of consumers. This structure is typically composed by activities and represent the flow of tangible and intangible goods and services [26]. The first step is to identifies the main activities in the value chain, then the second step is to understand what are the companies that participate in the different stages. In the literature review done before the main stages of the global semiconductor value chain and also the types of companies and organization active in each stage were already defined.

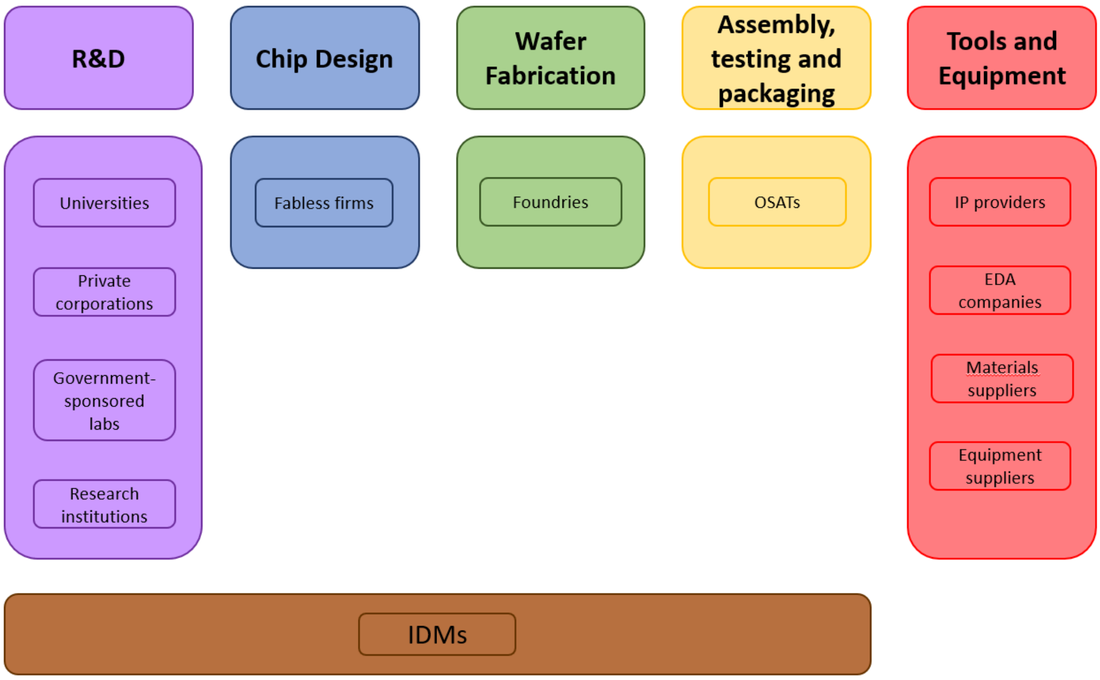

Figure 3.1: Stages of the semiconductor value chain and actors

Source: Author's Elaboration based on BCG (2021), SIA (2016)

It is important to highlight the flows that characterize the semiconductor value chain. The outputs of R&D stage are patents and technological breakthroughs that enable the manufacturing of more efficient and more powerful chips. Fabless firms are specialized in the design of chips, hence their output is the design of integrated circuits. Foundries manufacture chips according to what fabless firms have designed, and then send the chips to the next stage. OSATs convert the silicon wafers manufactured by foundries into finished chips ready to be assembled into electronic devices. The companies in the equipment stage provide different type of products and services to the other stages, from design software to manufacturing equipment and IP cores. IDMs, as saw before, perform vertically all the activities, from the design to manufacturing. When the demand is too high, IDMs can rely on foundries and OSATs to fill the gap between their capacity and demand.

Because the interest is on the Italian semiconductor value chain, a similar diagram using the data available was made.

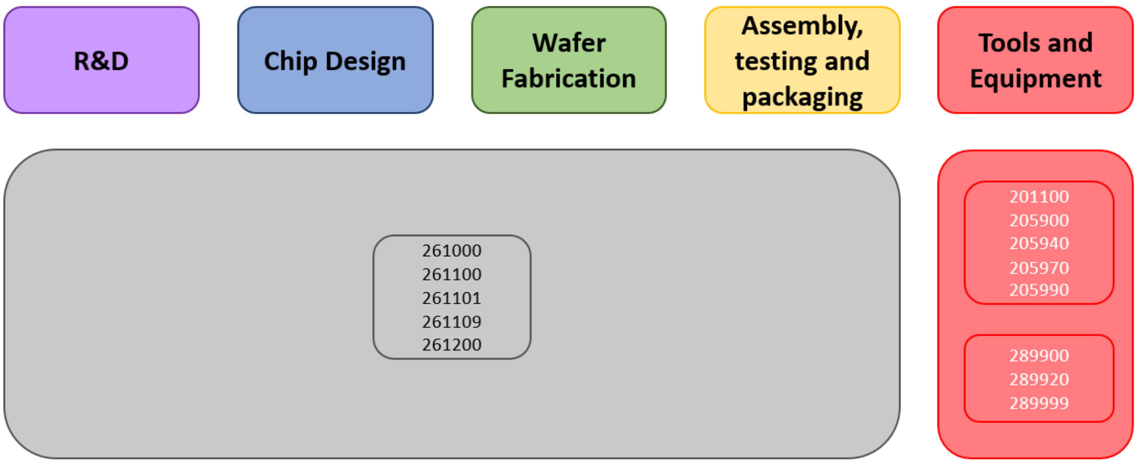

Figure 3.2: Breakdown of the ATECO codes by stages of the semiconductor value chain

Source: Author's Elaboration based on data from AIDA, 2022

From this diagram emerges that many ATECO codes that are related to the semiconductor value chain in Italy belong to the supporting activities like the production equipment, tools and software used in the production of chips. Specifically, the first group is related to the manufacture of industrial gases, chemical and electrochemical products, and the second one is related to the manufacture of industrial machinery and industrial robots for multiple use. Five are the ATECO codes related to the manufacture of electronic components and loaded electronic boards. The level of detail that characterizes the data do not enable to distinguish the specific stage of the chain where these companies operate, hence all the main stages from the R&D to the assembly, testing and packaging were considered. Indeed, in the set of companies someone can find IDMs like STMicroelectronics or fabless companies and OSATs, but it is not possible to distinguish all of them. Noted that R&D in the stages performed by firms belonging to the five ATECO codes were included, although it is known that this stage is usually related to universities and government-sponsored labs and programs, and less to firms. But looking at the budget of firms, it is possible to see that many companies invest in R&D, hence it can be considered as one of the activities performed by them.

Table 3.1: Breakdown of companies by ATECO codes

201100	75
205900	34
205940	382
205970	9
205990	67
261000	23
261100	40
261101	15
261109	529
261200	339
289900	28
289920	355
289999	548

Source: Author's Elaboration based on data from AIDA, 2022

Going into detail, these are the number of companies for each ATECO code. It is evident that there are many companies in Italy that manufacture equipment and tools used in the other stages of the chain, confirming what many studies argue about the specialization of Europe, so Italy, in this particular stage of the chain. But very interesting is also the number of firms belonging to the 261200 ATECO code, that is the manufacturing of loaded electronic boards. It is probably the ATECO code that mainly represents the manufacturing of chips. This highlight that there are many companies in Italy that produce chips but the majority of them are small and micro companies (from 0 to 49 employees). Putting together these data and what can be retrieved from previous studies, it is possible to say that Italy is “strong” in the supporting activities in the semiconductor value chain, and it has a good network of companies that manufacture loaded electronic boards, but they are too small to be competitive in the global market. Now three companies operating in Italy are presented: two are the biggest firms provided by the database but operate in different stages of the value chain, one is a producer of chips, the other produces chemical products used in the production of chips, the third is an important firm that operate in a niche of the semiconductor value chain.

3.1.1.1. STMicroelectronics

STMicroelectronics is a French-Italian company active in the semiconductor industry. Founded in 1987 by the merger between SGS Microelectronica, an Italian firm, and Thomson Semiconducteurs, the non-military division of Thomson SA [27], the company employs about 46.000 people in 2020 and has 11 facilities around the world, two in Italy [28]. STMicroelectronics is one of the main producers of electronic components used mainly in the consumer electronics, automotive and industrial sectors, and it adopt the IDM business model. The company produces many components from sensors and memory chips to power transistors and integrated circuits of all kinds. It is also leader in the technology innovation with 18.500 patents and almost 8000 people working in the R&D activities [28]. The products of the company are mainly adopted in the Smart Driving and the Internet of Things, but they are adopted in other sectors like videogaming consoles. With Infineon, the German company, STMicroelectronics is one of the main European players of the semiconductor value chain, and the role of Europe in such an industry is due to them. Hence, they have been crucial in the past, and will be more and more crucial in the future for the strengthening of the European semiconductor value chain. Their involvement in this challenge is fundamental to define in the right way the next step that enable Europe to become more relevant in the global market.

3.1.1.2. BASF

BASF SE is a German chemical company based in Ludwigshafen. It is one of the most important chemical companies in the world, with about 111.000 employees and more than 200 subsidiaries in 90 countries [29]. In Italy, the company is present in 11 locations, all in the northern regions. The company provides a very broad list of products adopted in many different industries like agriculture, constructions, pharmaceuticals and packaging. Regarding the electronics and electronical devices, the company offers different chemical products and advanced materials to their customers. Considering semiconductors, the company provides a wide range of process chemicals and solutions for the semiconductor processes such as photolithography, chemical mechanical planarization, and wet deposition. BASF SE operates in a niche of the semiconductor value chain, since it produces chemical products and provide solutions for the chip production, but it is very important, and it is one of the biggest players in the world. The company has been present in Italy for 75 years, and it considers Italy a strategic market for the group [30].

3.1.1.3. LPE

LPE in an Italian company founded in Milan in 1972. The company is specialized in the production of epitaxial reactors that are crucial for the manufacturing of chips [31]. LPE has about 70 employees and the revenues are around 20 million euros [32]. The company is based in Baranzate, in Milan, but has a branch in Catania, where there is the technology centre, and another branch is located in Shanghai because China is the most important market for the firm due to the presence of many of its customers. LPE is an excellence in the industrial machinery sectors because there are not so many producers of epitaxial reactors around the globe. This is why in 2021 the Italian government stopped the acquisition of the 70% of LPE by Shenzhen Investment Holding, a Chinese company, through the Golden Power. This tool in the hand of the Italian government was introduced years ago to stop acquisition of strategic Italian companies by foreign firms. LPE is strategic because its products are fundamental for the production of silicon wafers, hence the use of the Golden Power in such a crisis of chips was justified.

3.1.2. Geographical Scope

The second step of analysis is the geographic scope. In the original framework, this step is based on the analysis of the global supply and demand, looking at the trade flows for each stage of the value chain [26]. In this way, it is possible to see different trends like the regionalization of GVCs or their geographic scale. In this document the interest is on looking at the distribution of companies throughout Italy. First, firms are classified according to the province where the registered office is, then they are grouped together according to the region, and this is the current situation in Italy.

Figure 3.3: Distribution of companies in Italy, 2020-2021

Source: Author's Elaboration based on data from AIDA, 2022

From the map above, it can be seen the number of companies operating in each Italian region. In Italy there are 2395 firms operating in the semiconductor industry. From the table below, it is possible to see their classification according to the size: 31 of them are large (over 250 employees), 204 are medium, 769 are small, and 1391 are micro firms. Hence, the number of large firms is really low, about 1.3% of the total. This confirms that Italy is a country characterized by a strong presence of micro, small and medium firms, that are one of the pillars of the industrial environment in this country. The same maps of Figure 1.12 with the breakdown of companies by region and ATECO code are visible in Appendix A.

Table 3.2: Breakdown of companies by size

Micro	From 0 to 9	1391
Small	From 10 to 49	769
Medium	From 50 to 249	204
Large	Over 250	31

Source: Author's Elaboration based on data from AIDA, 2022

The majority of firms is located in the North. There are six region that register more than 100 companies, four of them are in the northern part of Italy (Lombardia, Piemonte, Veneto and Emilia-Romagna). This gap between North and South is visible also in other industries and it is an intrinsic feature of Italy, where the North is considered a more innovative and productive region than the South. Considering the classification of companies based on the dimension, the results are confirmed because the majority of large firms (over 250 employees) are in the North, particularly in Lombardia (15 large firms), but there are some exceptions like a couple of large firms in Abruzzo and Marche.

Table 3.3: Breakdown of companies by size and region, 2020-2021

	# Firms	Micro	Small	Medium	Large
Abruzzo	46	27	15	3	1
Basilicata	10	9	1	0	0
Calabria	19	14	5	0	0
Campania	66	45	18	3	0
Emilia-Romagna	326	178	113	30	5
Friuli-Venezia Giulia	65	39	22	4	0
Lazio	93	69	20	4	0
Liguria	43	29	13	1	0
Lombardia	758	401	251	91	15

Marche	83	54	19	8	2
Molise	6	5	1	0	0
Piemonte	204	111	70	20	3
Puglia	68	49	16	3	0
Sardegna	8	8	0	0	0
Sicilia	31	22	8	1	0
Toscana	163	91	64	6	2
Trentino-Alto Adige	25	14	9	2	1
Umbria	24	16	6	2	0
Valle d'Aosta	1	0	1	0	0
Veneto	356	210	117	26	3

Source: Author's Elaboration based on data from AIDA, 2022

Such a concentration of companies in the northern regions is due to the presence of customers in such regions. This phenomenon is called customer proximity and it has been already mentioned regarding the pivoting of semiconductor industry toward China. Customer intimacy is one of the main factors of regionalization in many other industries because it enables a closer relationship between customers and producers in the development of new products and services. The same can be said considering universities. In the North there are probably the most important universities related to engineering and electronics like Politecnico di Milano and Politecnico di Torino. Companies rely on universities for the developing of innovations and new technologies that could be used in the different stages of the chain, hence be close to them is really important for their activities in R&D but also to attract talents from these universities.

3.1.3. Governance

The third step of the analysis is related to the governance. In the framework of Gereffi and Fernandez-Stark (2016), governance is related to the control and coordination of the value chain. In particular, the interaction between actors that have different powers. There are five governance structures, determined by three variables: the complexity of the information shared between actors in the chain, how the information for production can be codified, and the level of supplier competence. The five governance structures are market, modular, relational, captive and hierarchy.

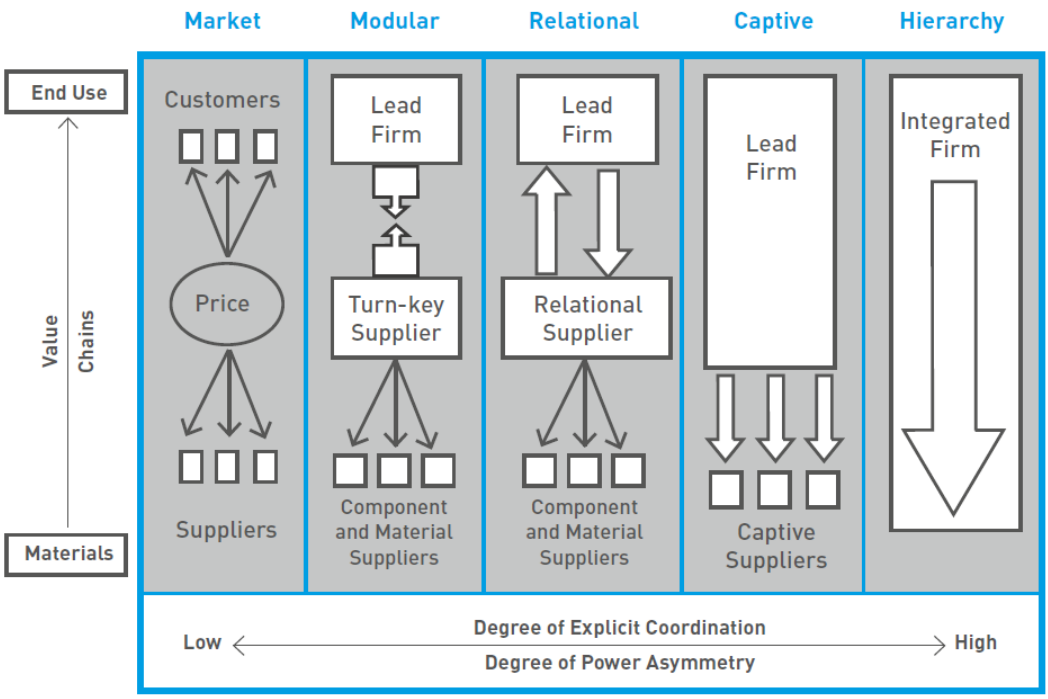

Figure 3.4: Typology of governance structures

Source: Gereffi, Fernandez-Stark, 2016, page 11

The problem is that this type of framework is used considering the entire global value chain, and this is not the case of this paper. In this section of the document, the aim is to identify what type of companies participate in the semiconductor value chain in Italy. The interest is to distinguish between single Italian companies and companies that are part of an Italian or a foreign group. In the set of companies, about half of them (1471) have a physical person as global reference shareholder. So, they can be considered as single companies that are not part of a group. They are usually the micro, small and medium companies mentioned before, that form the real industrial structure of Italy. The majority of this global reference shareholder are Italian, and only a small part are foreigners. All these companies are considered Italian although the global reference shareholder is a foreign person. Another set of companies do not present a global reference shareholder, hence are not relevant for the analysis. Instead, there are 543 companies that have a company as global reference shareholder. The global reference shareholder can be regarded as the parent company of the group, and these parent companies can be distinguished in Italian or foreign, according to the city in which they are located. Out of 543, 366 are Italian parent companies while 177 are foreign parent companies. In this second category of companies, there are the biggest companies of the set like BASF or STMicroelectronics, that are subsidiaries of the parent located around the globe. This type of analysis is useful to understand the number of companies in Italy that participate in the semiconductor value chain, and particularly, what are Italian firms or companies that decided to settle a subsidiary in the country. From the data, it is possible to see that more than the half of the companies are micro, small and medium companies. Some of them are companies that operate in a niche of the chain and offer a really important product or service, probably a unique one like Lpe or Technoprobe. The uniqueness that characterizes some of the products or services that firms provide gives to the companies a sort of bargaining power to negotiate with the MNEs, assigning them a crucial role in the GVC. Others, instead, are not really competitive, because they are small and offer something that could be found in the global market at lower prices. The low number of large Italian companies highlights the difficulty of Italian companies to become bigger enough to compete globally. Support this type of companies to become bigger and to be more efficient and competitive is probably one of the main goals the Italian government should reach in the future to build a more efficient and competitive Italian semiconductor sector. Another point is the low number of foreign companies that decide to invest in Italy. There are only 177 companies out of 2395 that decide to set a subsidiary in the country, and it is possible to believe that some of them were Italian companies that were acquired by multinational companies. The problem is that MNEs do not see Italy as a country where it is worth to invest in. Indeed, in the European Chips Act there is a section dedicated only to the attraction of foreign investment that is important for European countries to increase the participation of the region in the chain but also because Europe could get some spill overs coming out from these companies.

3.1.4. Upgrading

The fourth step of the analysis is the upgrading. Economic upgrading is defined as firms, countries or regions moving to higher value activities in GVCs in order to increase the benefits from participating in global production [26]. In the literature, four types of upgrading exist [33]:

- process upgrading, that is the reorganization of the production process or the introduction of a superior technology enabling a more efficient transformation of inputs into outputs;
- product upgrading, that means to move to more sophisticated product lines;
- functional upgrading, that is the acquisition of new functions to increase the overall skill content of activities;
- inter-sectoral upgrading, where firms move into new but often related industries.

Fernandez-Stark et al. (2014) [34] identified other additional types of upgrading:

- entry in the value chain, where companies participate for the first time in national, regional or global value chains;

- backward linkages upgrading, where local firms supply MNCs that are located in the country and are already inserted in a separate GVC;
- end-market upgrading, that is the movement into more sophisticated markets or into larger markets that require larger scale production and price accessibility.

In the global semiconductor value chain, the main types of upgrading are the process and product ones, and they are related. Advances in manufacturing process technology are called "nodes", and this term refers to the size in nanometres of the transistor gates in the electronic circuits [1]. This type of advancements in the process technology enables the development of newer and more efficient chips. Indeed, the smaller the node size, the more powerful the chip, as more transistors can be placed on an area of the same size [1]. This is the principle underpinning the "Moore's Law". The "Moore's Law" refers to Gordon Moore's perception that the number of transistors on a microchip doubles every two years, though its cost is halved [35]. Nowadays, the processors adopted in smartphones, computers and data centres are manufactured on 5 to 10-nanometre nodes and TSMC is expected to manufacture 3-nanometres chips in 2023 [1]. Hence, process upgrading and product upgrading are strongly linked determining the extraordinary pace of innovation of the semiconductor industry. In the last years many firms have experienced the functional upgrading due to the semiconductor crisis. One of the most famous examples is Apple that in its last products employs its own chips.

Considering the small and medium Italian companies mainly active in the equipment stage of the chain, providing unique products and services, the most common types of upgrading that can registered are the process and products ones. Indeed, in order to keep the pace of the innovation up in the sector, these firms need to stay on the edge of innovation in what they do. Cooperating with universities and research organizations, these companies are able to adopt new technologies that enable more efficient production processes, and to improve the products and services they provide to their customers. For the small and medium Italian companies is more difficult to achieve functional or inter-sectoral upgrading because these two types of upgrading require high capital investments to occur, and these firms are not able to bear the costs related to acquisition of new functions or related to the movement towards other related industries. But these types of upgrading must be the target of government and firms' initiative to reinforce the semiconductor value chain in Italy and to increase its global share. Bigger firms can be more competitive in the value chain because they can produce with lower costs and so provide their products or services at lower prices exploiting economies of scale. It is more likely that these small and medium firms achieved the "entry in the value chain" and the backward linkages upgrading in the past. Nowadays the "entry in the value chain" type of upgrading is more difficult to achieve for new Italian companies in the semiconductor value chain because the competition is very harsh and emerging in the chain is very complicated. The high investment required, the attraction of new talents and the necessity to secure supply contracts with fabless firms before building foundries, are the main reason why entry in the semiconductor value chain is so difficult especially in the production stage. Regarding the backward linkages upgrading, its achievement is less complicated than the "entry in the value chain" upgrading because MNCs can decide to change their suppliers if they find more efficient and cheaper suppliers, but it is still quite complicated because the customer proximity in the value chain is crucial and firms rely a lot on it, hence it is not simple to become the supplier of MNCs in the semiconductor value chain. Considering the large Italian firms in the semiconductor value chain, that are mainly related to the first four stages of the chain but also in the equipment stage, they experienced in the past all the four main types of upgrading. Take for example STMicroelectronics, one of the main European IDMs. It is a MNE spread throughout the world. To become what it is, it passed through all the stages that lead it to the current dimensions. For these types of companies, functional upgrading and inter-sectoral upgrading are easier to achieve because they have the resources to expand their business and to be profitable in the global market. For the same reasons, end market upgrading is much easier to achieve for large Italian companies. They have the capabilities to deal with stricter regulations in the new markets and to be profitable and competitive in the larger markets.

In the semiconductor value chain, as in many others, the high-skilled labour activities are performed in the developed countries while the low-skilled labour activities are performed in the developing countries. Italy is considered a developed countries because it is the second manufacturing country in Europe just after Germany, and it is a G7 country, hence it has a presence in high value-added activities like the R&D, chip design and equipment stages, while its presence in the other two stages, that are low value-added ones, is low, or even absent since there are no foundries or fabs that fabricate silicon wafers. In the last years the low value-added activities are becoming more and more high value-added because of the evolution of the machines and the processes that requires workers with better skills. Indeed, the famous Smile curve, used to represent the value chain and the value added by the activities that form it, is becoming flatter [2]. But it is known that an increasing presence in wafer fabrication is one of the objectives of the European Chips Act, in order to be less dependent on third countries like China or Taiwan for the manufacturing activities.

3.1.5. Local Institutional Context

The fifth section is related to the Local Institutional Context. This section talks about the conditions and policies that influence the country's participation to a GVC. One of the most influential initiatives in the EU is the European Chips Act approved on February 8th ,2022, by the EU Parliament on an EU Commission proposal. This Act allocate 43 billion euros [36] for the reinforcement of the European semiconductor value chain. The proposal consists of 3 points but the first two are the fundamental ones: a “Chip for Europe Initiative” and a framework to secure chip supply. The Chip for Europe Initiative focuses on the supporting of large-scale technological capacity building and innovation to enable the development and deployment of cutting-edge and next generation semiconductor and quantum technologies [19]. EU will build a virtual design platform to improve the design capacity of the region, and it will be accessible on open, non-discriminatory and transparent terms, stimulating the exchange of knowledge and cooperation among the different actors like design houses or IP and tools suppliers [19]. The Initiative has also the goal of accelerate the development of quantum chips and to support a network of competence centres that provide the necessary expertise to stakeholders. Additionally, the access to debt financing and equity will be facilitated through the “Chips Fund” that should support the development of the resilience of the chain enabling the growth of start-ups, scale-ups, and SMEs [19]. The second point is the framework to ensure the security of supply. This can be achieved attracting investments and increasing production capacity in the stages of the chain where Europe is weak, so semiconductor manufacturing and advanced packaging, test and assembly. The EU Commission proposes the implementation of specific projects distinguished in two types of first-of-a-kind facilities: Integrated Production Facilities and Open EU Foundries. These facilities would fill the gap that Europe has with other countries in the production stage of the semiconductor value chain. Indeed, Integrated Production Facilities are IDMs, so companies that perform all the activities of the chain, while Open EU Foundries are foundries, so fabs that manufacture silicon wafers where ICs are printed. We already know that foundries are mainly concentrated in Taiwan (92%) and China [1], determining high level of dependence of European companies on third countries foundries that could be related to disruptions in the supply of chips in case of crisis. To avoid these drawbacks and reduce the dependence of Europe on other countries, the Commission proposes the implementation of these two types of facilities. In the proposal is stated that the ultimate goal of the Act is not the complete independence but to reinforce the strengths of the region, develop new ones and to reinforce the interdependences with third countries to weaken their powers toward Europe. Other actual policies about the Open Strategic Autonomy aim at reinforcing the industrial and digital dimension in the long run [2]. Since 2021, the EU will introduce different initiatives to reduce the dependence on Asian and American chipmakers and catch up along the value chain. With the Semiconductors Alliance, EU wants to increase the value of the European production in the global market from 10% to 20% by 2030 [2]. Another important element characterizing the actions undertaken by EU to reinforce its semiconductor industry is the consolidation of the US-EU relationship. The introduction of the Trade and Technology Council (TTC) has the aim to reinforce this relationship regarding the new technological challenges coordinating their own industrial policies [2]. Finally, the EU understood that the competitive rules need to be adapted to the new environmental and digital goals of EU. Regarding that, the temporary rules for State Aid have been extended by June 2022 to accelerate the growth and to make the rules for the semiconductor industry more flexible [2]. EU provides other instruments to sustain the semiconductor industry that Italian companies can adopt. The first instrument are the industrial alliances. They can contribute to achieve the goals of the EU strategy. On one hand they can guarantee the global competitiveness of the European industrial sector. On the other hand, they contribute to the two biggest transitions in which Europe is committed: digital and environmental [2]. The main features of the industrial alliances are that they are built around a common objective, they tend to involve the majority of partners along the value chain, they are based on openness, transparency, diversity and inclusivity, respecting the competition rules, they are not involved in the decisional process, and they do not get direct financing [2]. The second instrument are the IPCEI (Important Projects of Common European Interest). Introduced in 2014 by the EU Commission to encourage State members to fund projects that clearly contribute to the economic growth, the occupation and the competition of Europe. The IPCEI integrate the regulation about State aids to sustain innovative projects limiting the competition distortions [2]. The semiconductor industry is one of the six fundamental sectors for the future development of industry. In 2018, the EU Commission authorized a project by France, Germany, Italy and Great Britain to provide public subsidies for a total value of 1,75 billion euros [2]. The project consists of 29 participants of 4 member States. The ultimate goal is to promote research and studies to develop technologies and innovative components that then can be adopted into downstream applications like consumer electronics or industrial machinery [2]. This is different to what China, for example, is doing with its plan "Made in China 2025". Adopted in 2015 by the Chinese government, this plan has the goal to make China the biggest industry in the world. In particular, China wants to become independent from imports in specific industrial sectors like semiconductors and ICT. Indeed, China results dependent on imports and consume the 60% of the global production of semiconductors. In its plan, Beijing wanted to increase the share of Chinese chips from 10% to 40% of domestic demand by 2020, and to 70% by 2025 [2]. The initiatives of the Chinese government regard investments through specific funds, but also regulation and application of the antitrust law to limit the access to the Chinese market for foreign companies [2]. Many studies like the one by BCG (2021) state that the self-sufficiency in the semiconductor industry is really difficult, if not impossible, to achieve because of the high costs required to be competitive in all the stages of the value chain, but also because high level of concentration can expose the industry to disruptions like natural disasters, infrastructure failures or geopolitical tensions. The same is happening in the US where government is adopting initiatives to sustain its semiconductor industry and to reduce its dependency to third countries in the sector. In January 2021, Congress passed the CHIPS for America Act, a legislation that authorize a series of programs to promote the research, development and fabrication of semiconductors within the United States [37]. The goal is to maintain the robust US manufacturing base in strategic industries, protecting high-priority supply chains in the event of international conflict or unforeseen crises like COVID-19 pandemic [37]. The CHIPS bill would provide $54 billion in grants for semiconductor manufacturing and research, tens of billions to support regional technology hubs and a tax credit covering 25% of investments in semiconductor manufacturing through 2026 [38]. The Unites States' share of global semiconductor fabrication capacity has been on a steady decline for decades, falling from roughly 40% in 1990 to around 12% in 2020 [37]. This is the consequence of the transition of US semiconductor firms from the vertical integrated model to the fabless one, maintaining the higher-value design elements for new, more capable chips and outsourcing their fabrication abroad, particularly to East Asia, that now accounts for around the 80% of global chip fabrication [37]. To reduce this dependence of US semiconductor firms, many US policymakers increasingly believe that American economic and strategic competitiveness requires a secure and significant domestic chip fabrication capacity. Hence, the CHIPS for America Act enables several programs to both expand US semiconductor fabrication capacity and to support continued research and development of advanced chips. The Act consists of mainly two sections: one dedicated to incentives, the second related to the research and development [37]. Regarding the incentives, the legislation provides financial assistance for the construction, expansion, or modernization of a semiconductor fabrication plant, or 'fab', in the United States to both private firms and public institutions. In the part related to research and development, the Act establishes the Multilateral Semiconductors Security Fund, a common funding mechanism among the Unites States and its international partners to promote the development of secure semiconductors and secure microelectronic supply chains [37]. The FABS Act is the second part of the action undertaken by the US government to incentivize semiconductors manufacturing. FABS offers private firms a 25% tax credit towards the purchase, construction, manufacture, or utilization of a semiconductor manufacturing facility or related equipment that will be used for the design or processing of chips [39].

Remaining in Italy, the Italian government has a set of powers that can be used in the defence and national security sectors, but also in other strategic sectors like energy, transport and telecommunication. Adopted in 2012 through a law (decreto-legge n.21 del 2012) [40], the Golden Power enables the use of special powers in relation to strategic companies. The powers of the government are the opposition to the acquisition of firms' participations, veto on the adoption of companies' resolutions, and imposition of specific conditions [41]. The article 1 of the law states that whoever acquires shares of firms that perform activities in the defence or national security sectors must notify it to the Prime Minister office. In this way the government can analyse the situation and take the right decision. In the last years, the Golden Power has been used many times in the ICT, related to the 5G infrastructure, and in the semiconductor industry to stop the acquisition of firms operating in these two sectors by mainly Chinese companies. During the COVID-19 pandemic, the Italian government strengthens it, expanding its scope to other sectors that are not so strategic to protect Italian firms from acquisition by foreign firms at rock bottom prices. In 2021, Italian government has received 496 requests to use the Golden Power, but it has been used only 26 times [42]. Regarding the 5G infrastructure, the government has set up a specific observatory to analyse the cases in the right way. In order to protect the infrastructure from Chinese companies like Huawei and Zte, the attention of the Italian government is on the use of technologies produced by foreign companies [42]. In March 2022, the Italian government has used the Golden Power to stop the acquisition of LPE by Shenzhen Investment Holding, a Chinese company [32]. LPE is an Italian firm located in Baranzate that produces epitaxial reactors used in the production of semiconductors. This fundamental role in the semiconductor value chain is the main factor that leads the Italian government to stop the acquisition. Many argues that the scope of the Golden Power is too broad, and that the notification obligation could discourage foreign investment that maybe are not predatory. Another pain point is the influence on the market dynamics that the Golden Power entails. The fact that the government can decide to stop or approve the acquisition of an Italian company orients the market in a certain direction, but this is not peculiar of a liberal system. Anyway, Golden Power is a crucial tool in the hands of the Italian government to protect Italian companies operating in strategic sectors, but probably some corrections in its use are needed to limit mainly distortions of the market dynamics.

3.1.6. Stakeholder Analysis

The last section of this analysis is the Stakeholder Analysis. Here the aim is to examine all the stakeholder involved and their main role in the chain, and how relations between these actors are governed at local level and which institutions are in a position to drive change. The main stakeholders in the Italian semiconductor value chain are located upstream and downstream. In the upstream part of the chain, the main stakeholders are universities, research organizations, government agencies and educational institutions. In the last years many universities have introduced in their university's programs courses focused on semiconductors, identifying the crucial role of them in the digitalized world. The Politecnico of Milan is probably one of the main universities active in the semiconductor value chain thanks to the PoliFab, the R&D centre of the university dedicated to the micro and nanotechnologies in collaboration with STMicroelectronics [43]. Other universities such as the University of Boulogne and University of Milano offer courses on Semiconductor Physics or Electrics Engineering, that prepare students to work in the industry in the future [44]. As said before in the input-output structure section, the collaboration between universities and semiconductor firms should focus on the development of innovation and breakthrough technologies that enable the evolution and the advancements in the industry, but also to attract the new engineers that would work in these firms after university. Other important stakeholders are the government agencies controlled by the Ministries like the Foreign Trade or the Economic Development whose goal is to attract foreign investments and to support the industry through industrial policies, enabling the growth of the industry. The Ministry of Economic Development is the organization that control the industrial environment and receive the notification related to the Golden Power. It is responsible to the draft of industrial policies and incentives for companies that want to do business in Italy [41]. Other organizations are the ones that gather together the producers in Italy. The most famous one is ANIE that is the association of companies active in the electronic components, and it is part of Confindustria [45]. These types of associations support the semiconductor industry representing the needs of the firms in the negotiating tables with unions or with governments. In the downstream part of the value chain there are the "customers" of the chipmakers, so the firms that use chips in their products. These firms belong to different industries such as automotive, consumer electronics, healthcare, defence and national security or telecommunication. The variety of chips required by these industries is very broad. The demand is more traditional and less advanced for the automotive, more sophisticated for telecommunication or consumer electronics which require the miniaturization of their components. In Italy the main customer of the semiconductor value chain is the automotive industry.

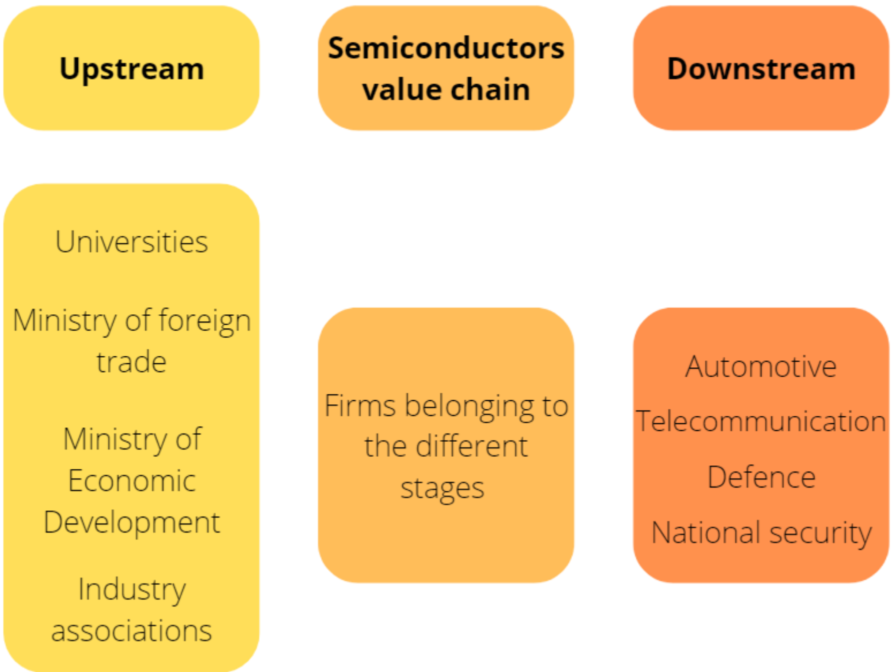

Figure 3.5: Customers of the Italian semiconductor industry

Source: Author's Elaboration based on BCG (2021), SIA (2016)

In the automotive sector, companies like Stellantis (ex-FIAT), Ferrari, Lamborghini or Maserati, that produce their cars in the country, use chips in many fundamental components such as ADAS, sensors and Infotainment to make cars work [1]. The share of chips in cars is even higher in electric cars that are becoming more and more present in the product lines of carmakers. Hence, importance of chips in the automotive is really high. From the BCG (2021) [1] it is known that automotive firms do not use cutting-edge chips, but they use older technologies (40nm or more) which are the chips in which Europe is stronger, and STMicroelectronics is one of the main firms that supply automotive firms with sensors and all the semiconductors used in the cars nowadays. The support and the growth of the production and supply of chips useful for such sectors should be the main goal of the government’s initiatives to protect such sectors from the global competition. In the telecommunication sector, the semiconductors underpin the development of the 5G infrastructure that will be the future of digital cellular network, offering network speed and reliability and almost no latency [46]. The connection between 5G infrastructure and chips is related to the evolution of smartphones that will be able to use the 5G wireless technologies, and to do that smartphone makers need adopt more advanced chips [46]. Semiconductors are also fundamental in the defence and national security industry. All the major defence systems and platforms rely on semiconductors, as much as all the platforms that citizens use for their daily operations [47]. Think about the cloud computing infrastructure that is adopted in the PA activities nowadays, or all the systems used for the protection of sensible data in the military sector. From this section, it is possible to see how important semiconductors are for the main European industries such as automotive, so it is important to protect them strengthening the semiconductor value chain.

4 Conclusion and future developments

This paper has looked at the Italian semiconductor industry, particularly its role in the global semiconductor value chain. The semiconductor value chain in Italy is not so developed and advanced, but it is specialized in the machinery and equipment production and supply. There are many firms but the majority of them are small and medium enterprises, with some large firms that are mainly subsidiaries of MNEs like STMicroelectronics or BASF. The analysis done in this paper has the goal to lead to the definition of what are the right initiative to implement to make the industry grow and to increase Italy's share in the global value chain. In the last years, the production capacity increased by 32% in volume between 2015 and 2020 and by 20% in value, with a global growth of 31% in the same period [48]. But simultaneously, there was a growth of the dependency on other countries (+5.8%) [48]. In this last section the aim is to define the development options that Italy, so Europe, should be able to adopt to strengthen its semiconductor industry. The main argument among the expert is the investment in the newest fabs to produce the 7-5-3nm chips. This type of investment is important mainly for geopolitical reasons, to reduce the dependency on the main producers. The problem is that it is not possible the creation of a new European global leader because the technologies are in the hands of firms like Intel, TSMC and Samsung. The only thing Europe, and so Italy, can do to increase its production capacity is to stimulate new investments of these firms in Europe. This type of initiative is already mentioned in the European Chips Act and is one of the main points of the Italian industrial policies. To gain the maximum from these investments, Europe should reinforce its design capacity on the most advanced nodes, sustaining the research on the design of digital micro-system, providing the access to the sophisticated CAD tools, investing in the development of talents in universities and research centres, in the promotion of start-ups, facilitating the creation of new firms [2]. Italy should also help all the others supply chains that enable the leadership of the European microelectronics. Another possible initiative is the promotion of the vertical integration of the national supply chains to create some large firms that can compete in the global market. Regarding these initiatives, Italy could use also the Next Generation EU funds. In the Italian PNRR, there are two lines of actions that account for 1.1 billion euros of investments [48]. The first line is related to innovation and microelectronic technology, and it provides 340 million euros to realize plants and advanced equipment to produce materials and innovative components in microelectronics. The second line is related to industrial policies of supply chains and industrialization, and it aims at financing strategic investments and supply chain projects, with an endowment of 750 million euros.

To growth and to increase its share in the global market, Italy should work on both the design and the manufacturing parts of the value chain. For both there are two lines of interventions: the first is related to the attraction of investments by the big global players of the industry, the second regarding the growth of the size of the Italian companies or, even, the incentives to set up such an ecosystem of firms in that specific segment. The attraction of foreign investments in the country is one of the pillars of the European Chips Act and is one of the main points of the PNRR of the Italian government. Since the emergence of an Italian multinational firm is very difficult to achieve because such a company would need the technological endowment that belongs to firms like Intel, Samsung and TSMC, and enormous capital expenditures are required, the easier path is to pull in such firms and allow them to invest in the country setting their facilities. It has been already mentioned the investment that Intel and TSMC have planned for Europe and also for Italy in the next years to improve the manufacturing capacity of the region. Italy already hosts two plants of STMicroelectronics in Agrate Brianza and Catania that produce silicon wafer of 300nm, but the Italian government would like to increase the manufacturing capacity of the country, hence the investments by other companies are needed to achieve the goal. The investment by MNEs could also be on other stages of the value chain, not only the manufacturing one, but also the design and the assembly and packaging stages because they are crucial and Italy is weak in these two parts of the chain, hence the investment here are very important to raise the relevance of the country in the world and also the share of it in the global value chain. Also, Italy should invest in the production of 20nm or less microchips because this is the trend followed by the American and Asian firms. Another important trend that Italy should follow is the one related to the business model. Many American firms are moving towards an IDM like business model, investing in manufacturing plant but also on the back-end and packaging. The IDM business model allows the company to control all the stages of the chain, reducing a lot the dependency on third parties and making the chain more resilient. Italian companies could follow this trend, but the development of an IDM firm requires high capital expenditures, that not so many firms can afford without some sort of aid. The increase in the manufacturing capacity in Italy, especially in the advanced nodes, is crucial, but to achieve the goal enormous investments and scale economies are required. This challenge cannot be managed by a single country, but it should be tackled at European level, with resources that are far higher than the current ones. Before, the importance of the back-end and packaging for the value chain was mentioned. These two activities are becoming more and more important because most of the innovation is concentrating here and many firms are investing a lot on them [2]. Hence, one of the challenges that Italy needs to face is the specialization in these niches that are not completely interested in the miniaturization, that is so expensive and capital intensive.

In the Geographical Scope section of the framework developed before, it was mentioned that the majority of the firms are located in the regions of the North, and the same can be said considering large firms, with little exceptions. This pattern is common of many other industrial sectors because the northern regions are historically the most advanced and the most productive regions, hence there is an economic gap between the North and the South that is very big and it is intended to grow in the next years. This gap has led to the impoverishment of the region that has not been able to develop as the North and it is one of the poorest regions of Europe. One of the main goals of the Italian government must be the development and the growth of the southern regions and take them to the same economical level of the North. The regions of the South can be the perfect locations for the investments of the MNEs and for the new firms that will born in the future in the industry. They can be the new hub of the Italian semiconductor industry and become an important point of the global semiconductor value chain. STMicroelectronics has invested in Catania in the past, and Intel has selected Sicily has one of the possible locations where it can invest. Due to the presence of STMicroelectronics, Sicily is an important region for the Italian semiconductor industry, but all the other regions like Campania and Puglia or Sardinia are perfect spots to consider. The South is a region with a lower labour cost and where the demand for labour is higher due to the high level of unemployment [49], but it is characterized by low-skilled workers because the high-skilled ones move towards the North to find a job. The industrial development of the South has been slowed down by different factors. The most famous ones are the corruption of the public institutions and the presence of the mafia in the region (these two factors are strictly connected), and the presence of few universities or research centres. The presence of criminal organizations in the southern regions and their bad "influence" on the public institution, from the municipalities to the governance of the regions, has been a deterrent for the investments of global players in many industries because these companies did not want to deal with them for the fear to lose money. Interventions by the Italian government and by the judiciary institutions to reduce the power of these organizations and the corruption can attract large companies and their investments and ease the economic activities. An element that companies consider when they decide where to invest is the presence of a network made by universities, research centres and organizations that can help them in the innovation and technological improvement, and from which they can employ new talents. For the STEM courses, the best universities are in the North (Politecnico di Milano, Politecnico di Torino), but there are some exceptions like the Federico II of Naples. In general, the most important universities are located in the North, and every year there is a migration of student from the southern regions to the northern ones [49]. This leads to the impoverishment of the region, because these students rarely will come back, reducing the number of talents that can be employed by companies. Also, the presence of research centres is scarce, making the region less attractive for firms willing to make investment because companies do not have the right support for their research about technological improvements and innovations. All these elements determined the current situation, but they can be solved through a collaboration between firms and government. On one hand the government should invest in the universities of the South, increasing the resources of them to improve the offer for the students in order to keep them in the regions. Universities should become the main element of a network that consists of research centres, organizations that promote studies and project related to semiconductors, with the aim of provide the technological knowledge and innovation, and the talents that can be used by semiconductor firms. On the other hand, companies must be committed to invest in the region setting up R&D centres, facilities or design divisions that can revive the industrial sector in the region. This will help to close the economic gap between the North and the South that has increased a lot in the past years without anyone doing something to stop it. It was already mentioned before the relevant role of Italy in some important industrial sectors that use microchips as the automotive, the aerospace and the industrial machinery ones. Spread all over the country there are many facilities of such companies belonging to these industries, from the North to the South. Through the paper of Yeung (2022), it was highlighted the importance of customer proximity in the outstanding growth of the role of East Asia in the semiconductor industry. In Italy there are industrial clusters where firms that participate in the same value chain located their facilities in the same area to facilitate the business. This is a very common practise of firms, particularly in the automotive industry. The importance of clusters for the economic growth of a region are highlighted by many studies. Hence, it can be suggested to the government to incentivize the location of semiconductor firms' facilities in the clusters already present in the Italian territory, for example the Motor Valley in Emilia Romagna. Industrial clusters have many positive outcomes both for the territory and for the companies participating in it. The territory can benefit from the grouping of firms in the same area thanks to the higher number of people employed reducing poverty in the region or the possible spill overs that can lead to the creation of new firms and a further industrialization of the region. Firms belonging to the clusters can benefit from lower logistic costs and easiness in doing business related to the closeness with their partners, a more flexible and dynamic labour market, and more possibilities to involve firms in innovation and R&D projects that can lead to breakthroughs benefiting all the clusters. As in the case of the development of the South, this is something that can be realized through a collaboration between semiconductors firms and government because the capital expenditures required are very high and both the parties are not interested to bear the cost alone. All the initiatives listed here are very ambitious and expensive to realize both in terms of time and in terms of investments required. They perfectly match with the main goals of the European Chips Act, the legal framework introduced by the EU Commission to sustain the European semiconductor industry.

As mentioned at the beginning of this section, in the PNRR there are 1,1 billion euros allocated to fund the building of infrastructures to produce chips and innovative and strategic projects related to the semiconductor value chain [48]. Then the Italian government has allocated almost 5 billion euros to promote the research and the development of new technologies in the field. But these investments are not sufficient to reach the ambitious goals linked to the initiatives listed here. This is why is important that Italy and the other European countries understand the relevance of this challenge and decide to allocate together more and more resources to realize all the projects and the initiatives required to strengthen the European semiconductor industry. This is what is needed to compete with US and China and the other nations in the global market, to give Europe a relevant role in such a crucial industry. This is what Italy must do to put itself on the map and become an important point of the semiconductor value chain. Future developments that can arise from this paper can be related to a more precise map of the industry in Italy, or a replication of the analysis reported here for the other main European countries like France, Germany or UK, what are the stages of the value chain in which they are strong, and in which they are weak, what are the main companies there. This work can be interesting to make a comparison between them. Another interesting development can be a monitoring of the current initiatives undertaken by different countries to respond to the crisis and their results, understanding what will be successful and what will be a failure. Someone could find interesting a deepening analysis of the current policies in Europe and around the world, and the possible next steps that can be taken to regulate and strengthen the semiconductor industry.

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A Appendix A

A.1. Geographical Scope

Here there are the three maps showing the breakdown of Italian companies by region and category of ATECO codes. Figure 15 shows the Italian companies belonging to the 20- ATECO codes, Figure 16 the Italian companies belonging to the 26- ATECO codes, and Figure 17 the Italian companies belonging to the 28- ATECO codes.

Figure 0.1: Italian companies belonging to "Manufacture industrial gases and chemical products"

Source: Author's Elaboration based on data from AIDA, 2022

Figure 0.2: Italian companies belonging to "Manufacture of electronic components and loaded electronic boards"

Source: Author's Elaboration based on data from AIDA, 2022

Figure 0.3: Italian companies belonging to "Manufacture of other machines for special uses"
Source: Author's Elaboration based on data from AIDA, 2022

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