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Success and risk factors in strategic alliances:

the case of alliances after the semiconductor shortage in the automotive industry

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INTRODUCTION

2020 was the year that marked the beginning of a severe crisis for the automotive sector, which still continues, caused by the shortage of semiconductors. This has impacted approximately 169 sectors, but that of the automotive was undoubtedly the most severely affected. In fact, semiconductors are an essential component for building a car, as they are needed to control any function, such as the infotainment system, or driver assist systems, and much more. Just think that on average in a car 1400-1500 semiconductors are required, up to over 3000 in the most technologically advanced car models.

Given the situation, the automakers found themselves forced to remove some functions from their car models, up to a strong cut in production. To prevent such a shock from happening again in the future, many of them have decided to try to make their supply chain safer. This would be possible thanks to the formation of strategic alliances directly with the suppliers of this precious component, that it would allow to secure the supply of semiconductors in future.

Therefore, this thesis aims to analyse the phenomenon of semiconductor shortage, with a focus on the automotive sector, and how the response to the crisis of many car manufacturers has been the formation of strategic alliances with suppliers. It will be discussed strengths and weaknesses of strategic alliances, and what are the mechanisms that prevent the emergence of opportunistic behaviours within these, thanks to the use of a case study.

The first chapter focuses on literature review of strategic alliances. In particular on what are reasons and factors that influence the adoption of this collaboration strategy, types and stages for alliance formation, how to manage the relationship between the parties involved, and factors that affect the success or the failure of alliances.

The second chapter deals with the semiconductor industry, especially the various steps of the value chain. First, a brief analysis of the industry will be carried out, then the description of the various processes that form the value chain of semiconductors, concluding with those that are the main macro trends that are having an impact on it.

The third chapter shows what are the causes of semiconductor shortage, and what was the impact on the main sectors affected, bringing particular attention on the automotive industry.

Finally, the fourth chapter will present the case study used. This is the strategic alliance between the Volkswagen Group and STMicroelectronics. Initially, the impact of the crisis on the Volkswagen Group will be analysed. Subsequently, the focus will be on the strategic alliance, going to analyse what were the reasons that led to its formation, the strengths regarding the choice of partner, and mechanisms to combat the potential emergence of opportunistic behaviours which can lead to failure. A comparison with Tesla, a car manufacturer that did not need to resort to a strategic alliance in response to the semiconductor crisis, will also be proposed.

1. COLLABORATION STRATEGIES: STRATEGIC ALLIANCES

1.1 DEFINITION OF STRATEGIC ALLIANCE

Within the literature it is possible to find multiple definitions of strategic alliance. However, they all share the following criteria:

- an agreement between two or more companies to achieve an objective of common interest;
- the companies involved retain their legal autonomy;
- control of alliance management and the resulting benefits are shared by all participating companies;
- the companies involved must contribute to the alliance through their own resources and capabilities. (Išoraitė 2009)

A first distinction in strategic alliances is that between equity strategic alliance and non-equity strategic alliance. The equity strategic alliance requires an investment in equity from the partners, and the most common forms of this type of alliance are joint venture and equity participation. In the joint venture two partners, who remain independent, create a new company whose ownership is jointly held. In equity participation a company buys an equity ownership into another company. The non-equity strategic alliance does not require the investment of the companies in equity, because they are based substantially on contracts. Common types in this case are franchising and licensing. Franchising is an agreement by which a company grants the right to market its products or services using its name or trademark to another company, against payment of a fee. Licensing is a contractual agreement whereby a company obtain the right to use a proprietary technology of another one. A more detailed definition of the types of strategic alliances will be provided later in paragraph 1.4. (Culpan 2002, p.67)

A second distinction concerns vertical, horizontal and diagonal alliances. Vertical strategic alliances are established between companies that belong to the same industry, but carry out different activities within the value chain, and therefore they are not competitors; a very common example is the alliance between customer and supplier. Horizontal strategic alliances arise between companies that belong to the same industry and carry out the same activities within the value chain, and therefore it is a cooperation with a competitor;

this type of alliance is common in the automobile manufacturing and airline industries. Finally, diagonal strategic alliances take place between companies belonging to different industries. (Culpan 2002, p.67)

1.2 REASONS FOR STRATEGIC ALLIANCE

There are several reasons why a company decides to enter into a strategic alliance and collaborate with one or more partners. Moreover, in the reasons listed below, not necessarily one excludes the others.

Market entry and market position-related motives

Companies can decide to join an alliance in order to have access to an international market of particular interest. This because the collaboration with a company, that has complementary skills and resources, can help to acquire a better market position or accelerate entry, compared to an approach in which the firm proceed alone. Also in this regard, a company can opt for a collaboration to avoid entry barriers of international markets, which are posed by legal, regulatory, and/or political factors. The collaboration with a local firm can help to reduce this type of risks, and also improve knowledge of the new market. In markets where a company is already present, alliances can help to increase or strengthen market position, always relying on complementary resources and capabilities of another company. It is also possible to protect market positions, that have already been acquired, from a foreign competitor, by attacking the company in its home market. (Varadarajan, Cunningham 1995)

Product-related motives

The alliances can be useful for a company to fill gaps in the current offer of products or services, or to expand its offer and reach a greater target of consumers. They can also be useful for differentiating or adding value to the offer. (Varadarajan, Cunningham 1995)

Product/market-related motives

In this case a company, seeing that gradually its market becomes more and more stagnant, can look for new markets where to offer its own specific product. This because in the current market this offer no longer brings high profits, and in this way, it can achieve higher growth margins. It is also important to underline how this modality can be useful in case alternative or complementary technologies may emerge, since there is the necessity to remain at the forefront in these new emerging markets. (Varadarajan, Cunningham 1995)

Market structure modification-related motives

It is about reducing the potential threat of future competition by creating alliances with competitors. In addition, it is also possible to raise or strengthen entry barriers to the market in which a company operates, for example by preventing new entrants from reaching the volume needed to benefit from economies of scale. In the same way, alliances can be useful to overcome entry barriers by combining the capabilities of a company with those of another company. Some types of alliances, which favour technological revolutions, can also lead to changes in the structure of a sector and in the basis of competition of companies in the industry. (Varadarajan, Cunningham 1995)

Market entry timing-related motives

An alliance can be used to accelerate the pace of product development or the rate at which a product enters a market. (Varadarajan, Cunningham 1995)

Resource use efficiency-related motives

It is about increasing resource efficiency, for example by reducing the cost of manufacturing or marketing. The cost of manufacturing can be reduced either by recourse to economies of scale, scope, or experience, or by the fact that some factors can be found at a different cost by different companies. To reduce the cost of marketing, a company could use the distribution channels already owned by the company with which it establishes the collaboration. (Varadarajan, Cunningham 1995)

Resource extension- and risk-reduction related motives

When a company is facing large expenses, the alliance can be useful for sharing resources. This is often the case of small companies, because the costs of R&D to develop new products or improve existing ones are considerable, but in the same way also the costs of remaining competitive in the market. Despite this, even large companies, which face entry into international markets, are looking for a way to get more resources, because the necessary investments are costly. The same applies to the sharing of risks, and therefore to be less exposed to uncertainty arising from dealing with large investments or technological, market, or other uncertainties. (Varadarajan, Cunningham 1995)

Skills enhancement-related motives

One of the main reasons, which leads to the formation of an alliance, is to facilitate the learning of new skills that the company individually would not be able to create. It is important to underline that sometimes this learning can move only towards a company, that benefits most from the relationship, and would be able to dominate it by renegotiating terms in its favour. Working with a partner can also improve existing capabilities. (Varadarajan, Cunningham 1995)

1.3 FACTORS INFLUENCING THE ADOPTION OF STRATEGIC ALLIANCE

The propensity of a company to enter into a strategic alliance can be influenced by both, internal factors and external factors. These are grouped into three categories: firm, industry, and environmental characteristics.

Firm characteristics

Generally speaking, companies that are less likely to enter into a strategic alliance are those that already have the resources and capabilities they need, or those that have the financial means to purchase them. Nowadays however, companies operating in global markets, to compete effectively and maintain their product-market portfolio, often have to resort to alliances to expand their resource base. Otherwise, they would have to reduce their product-market portfolio only to the markets in which they are certain to dominate. Another factor, that could be influential, is the fact that a company that have already participated in an alliance with an outcome that was positive, it will have a greater propensity for the future as well. Finally, it must also take into account the culture and attitude of top management regarding this topic. (Varadarajan, Cunningham 1995)

Industry characteristics

In this case, companies are more likely to enter into a strategic alliance when the volumes to benefit from economies of scale are lower than those obtained operating in solitude. Other significant factors may be those regarding competition. The threat of new entrants and that of substitutes can make competition very tough, and this can encourage the creation of strategic alliances. (Varadarajan, Cunningham 1995)

Environmental characteristics

In this case, the factor that most affects the choice is technology. Companies operating in an environment subject to many technological changes often lack resources and capabilities, and this is why they are more likely to enter into a strategic alliance with partners that have complementary ones. Another aspect to consider is the political, legal, and regulatory environment in which the company operates. The regulatory intervention of the country can affect the freedom of companies to form alliances, as it establishes what are the main obstacles and opportunities for alliance formation. The policy regarding tax incentives and international trade is another determining factor in the decision to enter into alliances with overseas partners. (Varadarajan, Cunningham 1995)

1.4 TYPES OF STRATEGIC ALLIANCE

Among the various types of strategic alliances, the main ones are the following.

Joint venture

In a joint venture "two or more firms create a jointly owned legal organization that serves a limited purpose for its parents". (Todeva, Knoke 2005)

Therefore, two or more companies join own resources for a specific purpose, however without incurring in the risks typical of the mergers and acquisitions, since there is no change in the control of one of the parties. The aim of this type of collaboration can be, for example, the development of a technology, the commercialization of a product, the acquisition of assets, or an investment in marketing. (Miller, Segall 2017, p.292-294)

There are two main types of joint ventures: entity joint venture or contractual joint venture. In the case of entity joint ventures, the parties become joint owners of a new entity, which can be a limited liability company, corporation, or other. The parties are required to provide assets such as cash, equipment, facilities, and/or personnel to the new entity, in exchange for the equity of this one. In this case, the partners share the costs and profits of the company, and they are solely responsible for the part of the capital they have paid up. In the case of contractual joint ventures, the parties enter into the agreement for the implementation of a joint project with the aim of sharing the profits. There is a contract that establishes the obligations and rights of the parties in relation to the partnership, which must be respected by the parties separately, in fact there is not the creation of a new jointly owned entity. (Miller, Segall 2017, p.292-294)

R&D consortia

R&D consortia is an "inter-firm agreement for research and development collaboration, typically formed in fast-changing technological fields". (Todeva knoke, 2005)

It is often formed by manufacturing companies, sometimes even with government support, with the aim of conducting collective research regarding R&D. Companies joining these consortia benefit from cooperating for innovation and from being able to share expenses and resources, and, also, to access a large pool of talents and experiences. (Yang 2020)

On the other hand, there are also risks in this type of alliance, because often in the consortia are present non-competitors and competitors of a company. Non-competitors can create benefits regarding the share of new knowledge and technologies diversity. However, competitors have the advantage of having a similar technology as a starting point for collaboration, but companies are exposed to the possibility of an opportunistic behaviour of competitors, as there is a risk of expropriation of valuable and unprotected knowledge. (Yang 2020)

Franchising

In franchising "a franchisor grants a franchisee the use of a brand-name identity within a geographic area, but retains control over pricing, marketing, and standardized service norms". (Todeva, Knoke 2005)

The franchisor is the owner of products or services that grants to the franchisee the right to market them using his own distinctive signs, know-how and assistance. The franchisee is the operator that must comply with the management, marketing standards, and models decided by the franchisor. The relationship is regulated by a contract that establishes the terms of the agreement and in particular the entry fee and royalties. The entry fee is the economic consideration that have to be paid by the franchisee to the franchisor, due to a series of services that it made available to start the business. Royalties are compensation in proportion to the activity carried out by the franchisee, and paid to the franchisor for the remuneration of intellectual property rights. (Vinturella, Erickson 2003, p.289-294)

In this agreement, the advantages for the franchisor are: reduction of the entrepreneurial risk, which is shared with the franchisee; access to the capital; fast expansion and growth of the brand; achievement of operating efficiency and economies of scale. The disadvantages are: loss of control; not immediate return on investment. On the other hand, the advantages for the franchisee are: business assistance; reduction of entrepreneurial risk; knowledge of the brand; reliable suppliers; lower operating costs. The disadvantages are: limits of choice; payment of royalties. (Vinturella, Erickson 2003, p.289-294)

Licensing

In licensing "one company grants another the right to use patented technologies or production processes in return for royalties and fees". (Todeva, Knoke 2005)

In this case, only the right of use is transferred, but not the property. The company granting the right is called licensor, while the company that receives it is called licensee. The licensor makes available its knowledge against payment of a royalty, for the exclusivity of the same, that it represents the main source of gain of the licensor. (Sherman 2003, p.361-362)

From the point of view of the licensor, the reasons for entering into this type of contract are: allows to its technology or other capabilities to spread in the market more widely and faster than it could do alone; share the risk and cost of development and distribution. From the point of view of licensee, it is advantageous because: allows to acquire a technology that does not possess very quickly; it is less expensive than developing a technology in solitude. The negative side of this type of contract is that the licensor may face highly competitive risks. In fact, at the end of the contract with the licensee, the latter may have acquired sufficient knowledge to avoid recourse to another contract of this kind and place himself directly on the market as a direct competitor of the licensor. (Sherman 2003, p.361-362)

Outsourcing

"Outsourcing is a business agreement, either domestic and/or international (known as offshoring), and strategic management initiative for gaining a competitive advantage of a firm by contracting out their existing internal and/or external non-value-added functions, and/or value-added functions, and/or core competencies to competent supplier(s) to produce products and/or services efficiently and effectively for the outsourcing firm". (Pang, Zhang, Jiang 2021, p.1-5)

The main reasons that push the companies towards the outsourcing are: the use of the minimal cost in order to reach the maximum result, concentrating only on central activities that are the source of competitive advantage, and relying to specialized suppliers for the other activities, carefully selecting the partners; the need of external expertise. (Pang, Zhang, Jiang 2021, p.1-5)

However, there are some risks: strategic risk, operational risk, intrinsic risks of atrophy, and intrinsic risks of location. Strategic risk is defined as the risk of opportunistic behaviour from both, the outsourcing firm and the supply firm. In fact, in the case of outsourcing firm, managers may not hire qualified supplier, while, in the case of supply company, the latter may not work as expected. Operational risk refers to problems of communication or cooperation during the period of outsourcing between the firms. Intrinsic risk of atrophy means that if the outsourcing firm does not invest in the development and renewal of internal skills and competences, this can lead the company to empty itself and lose its value. Intrinsic risk of location refers to risks of outsourcing in a remote region, because each region has its own unique cultural and political background. In this case, it is necessary that the manager understand the supplier's country in advance, otherwise, the outsourcing firm can increase the possibility of extra costs. (Pang, Zhang, Jiang 2021, p.1-5)

1.5 STAGES FOR ALLIANCE FORMATION

The process for forming a strategic alliance can be divided into the following four stages: strategic decision, configuration of a strategic alliance, partner selection, management of a strategic alliance.

Strategic decision

Strategic decision refers to the phase in which an analysis of the company is conducted, and it can be defined the necessity to evaluate the entry into a strategic alliance. At this point, this stage can be divided into three subgroups of activities: situation analysis, identification of cooperation potential, evaluation of shareholder value potential. (Bronder, Pritzl 1992)

In the situation analysis, mission, value potential, and strategic excellence position/core competencies are examined. The mission represents the goal of the company, what is the purpose of its existence. It acts in the present and guides all strategic decisions, helping the company to achieve the desired future projection, and establishing ways to achieve the predetermined results. The value potential includes market potential, financial potential, human potential, and cooperation potential. Each of these potentials has a life cycle, and, therefore, it becomes important to monitor them, to understand the current life cycle phase of the firm. Finally, the company must assess whether it has the core competencies to achieve its mission. The core competences refer to the salient characteristics of the company that differentiate it from the others, and make it competitive. (Bronder, Pritzl 1992)

In the identification of cooperation potential, the company must estimate if the cooperation through an alliance is more convenient than operating individually or through a merger or acquisition. (Bronder, Pritzl 1992)

In the evaluation of shareholder value potential, it is important to measure the contribution that each strategic alternative gives to the shareholder value. Some value drivers must be considered for each alternative, such as the duration of the sales growth rate, profit margin, investments in fixed assets and working capital, and their impact on the total value. A key aspect to keep in mind is that costs arising from coordination problems and conflicts may impact the alliance. It is therefore necessary to include this type of costs in the analysis. (Bronder, Pritzl 1992)

Configuration of a strategic alliance

This stage includes decisions about the field of cooperation, the intensity of cooperation and the opportunities for multiplication.

Field of cooperation refers to the direction of cooperation and the value chain activities that are involved. For the direction, it can be identified three types of alliances: horizontal, vertical and diagonal. As described above in this chapter, the horizontal alliance involves companies that belong to the same industry and carry out the same activities; the vertical alliance includes companies that are part of the same industry, but carry out different activities; the diagonal alliance includes companies operating in different industries. Having defined this aspect, it becomes important to decide which activities of the value chain should be chosen and which are the competences to develop jointly with the partner. (Bronder, Pritzl 1992)

In the intensity of cooperation, it is necessary to consider the factors influencing it, such as time frame, resource allocation, and degree of formalization. Starting from the time frame, partners must decide the time horizon of the alliance, and therefore if it is an alliance in the short or long term. For the resource allocation, there are two different options to choose from: a pool of resources where both partners contribute with their own resources, or to perform certain activities together while keeping resources separate. The last decision concerns the degree of formalisation, in which the legal form of the organisation, the detailed roles of process and communication, mutual control, and organisational structure are defined. (Bronder, Pritzl 1992)

Opportunities for multiplication refer to consider the expansion of the alliance to more than one partner. This is because multiplying cooperation can create a network of different companies, in which each contributes to the growth of the system through its specific skills. (Bronder, Pritzl 1992)

Partner selection

This is one of the most important decisions, in which a company must evaluate the choice of the best partner for the alliance, based on an analysis focused on fundamental, strategic, and cultural fits.

Fundamental fit is achieved when the value potential is increased by the fact that activities and skills are complementary. (Bronder, Pritzl 1992)

Strategic fit indicates the compatibility of strategic objectives between partners. In this case, some important aspects must be taken into account in the evaluation of the partner, such as: harmony of business plans, joint specification of the appropriate configuration, common timing for the achievement of objectives. (Bronder, Pritzl 1992)

The cultural fit shows a compatibility between the geographical and internal culture of the partners. This can lead to the success of a long-term alliance, so an analysis of each culture is important to identify potential critical areas. When two different cultures meet, there are different kinds of reactions: pluralism cultures, in which the two cultures coexist; assimilation cultures, in which the positive elements of both cultures unite to form a new one; transfer cultures, in which one partner tries to transfer his culture to another partner making him lose independence; culture resistance, in which there is a risk of leading the alliance to failure. A more detailed analysis of the partner selection will be provided later in paragraph 1.6. (Bronder, Pritzl 1992)

Management of a strategic alliance

At this stage the management of the companies, that are part of the strategic alliance, must understand that the cooperation is a continuous process of negotiation and seeking agreements, and that the ability to plan and control is limited. Particularly important are the phases of contract negotiations, coordination interface, learning adaptation and review. (Bronder, Pritzl 1992)

In the contract negotiations phase, it is important to specify the objectives of the negotiation. These can be: risks limitation in the event of the failure of the alliance; limitations to the partner for being able to take part in another alliance; possibility of participation in future developments; participation in the partner's growth potential. In this way the final contract is established, which also specifies legal restrictions, government regulations, and political and fiscal aspects. (Bronder, Pritzl 1992)

In the coordination interface phase, an experienced manager is assigned to coordinate the alliance. Moreover, the management of a strategic alliance has a dual character: on one hand, a task-oriented management focused on specific aspects of the task in question, on the other hand, an interaction-oriented management focused on the interpersonal aspects of managers. (Bronder, Pritzl 1992)

In learning adaptation and review phase, which takes place after the signing of the contract and the start of cooperation, conflicts may arise between the partners. In this case, it is good to keep in mind that not all conflicts are negative, in fact they can also lead to positive outcomes if they are managed in an optimal way. It is therefore important that the goals of the alliance are updated and redefined, as well as the skills that have been jointly built. (Bronder, Pritzl 1992)

1.6 CHOICE OF PARTNER

In the analysis carried out for the choice of the partner in the alliance, it is necessary to take into account some factors: complementary skills of the partner, cooperative cultures between companies, compatible goals between companies, commensurate risk levels.

Complementary skills

In the search for a partner, one of the fundamental aspects is that the partner must have complementary resources. Firstly, a comprehensive analysis of the potential partners must be carried out, covering not only the size of the financial contribution, but also capabilities, technology and markets. A second step is to look for something that a potential partner can do specifically and that can be interesting for the company that is doing the research. It is therefore important to assess the skills, experiences, and potential real contribution of a partner. An important consideration is that in alliances each partner must be willing to give as much as they get, because if it is only one of the two partners to make a contribution, the alliance is doomed to fail. And not only the partners have to contribute, but they must depend on each other. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Managers should choose to form an alliance only with partners that meet a specific need, offer skills, experience, and know-how, that can be applied to the development of the products or services that the company offers. However, each partner must benefit from the collaboration, otherwise it becomes a one-sided alliance, in which only one of the firms has an advantage. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Cooperative cultures

The first step in creating cooperative cultures is to seek symmetry between the two companies. Strategic alliances are more successful when there are only small differences between companies in terms of size, financial resources and internal working environment. This type of symmetry should also be present at the top level of management, which becomes a factor of particular importance in case there is no symmetry in the size. Nevertheless, cooperation between cultures becomes difficult to maintain when the partners of an alliance are located in different countries. That is because the attitude in work can vary a lot from culture to culture. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Managers should pay attention that employees in their company are able to recognize cultural differences, and to act without misunderstanding the signals of the partner. However, it is time-consuming to find partners with cooperative cultures, and this is why past experiences that the potential partner has had in alliances or visits to company headquarters can help. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Compatible goals

Goals evaluation is particularly important, because when the goals of each partner are not taken into account, alliances tend to fail. In addition, it is necessary to understand how the objectives of the potential partner can influence the success of the company that is seeking the partner. An ideal situation would be where strategic objectives converge, while competitive objectives diverge. Another important aspect is the clarity of the objectives, in fact ambiguous objectives, blurred directions and uncoordinated activities can be the cause of the failure of the alliance. To avoid this, it is necessary to ensure that the companies have synchronised goals, and then carry out frequent assessments of what has been achieved in terms of objectives. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

To prevent problems regarding the conflicts between the partners' objectives, managers should carefully analyse the past actions of the partner and use them as clues for what might be the real objectives. Discussions with clients or former employees can also help. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Commensurate levels of risk

The alliance seen as a way to share risks with a partner is becoming increasingly a necessity, especially in industries where changes happen very quickly. At the same time, the company must be certain that there is a commensurate level of risk between the participants. In this regard, it is necessary that the risks are clearly distributed already at the beginning of the alliance. Moreover, the alliance should not be seen only as a way to share risks, but first of all as a way to learn as much as possible from a partner. If one of the companies learn more than the other, the risks will no longer be balanced, and this will lead the alliance to failure. This, with the consequence that the partner who has learned less will have a substantial disadvantage, compared to the other in the market. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

Managers should pay attention also to the possible negative sides of an alliance. The first concern is the fact that the partner could appropriate of private information, not related to the alliance. In this case, the role of the gate keeper becomes important to ensure that access to non-alliance information is protected. The second risk is that the partner fails to meet the future financial contributions, required by the alliance. This is why managers must carefully assess future financial needs, and limit the choice to those partners that will not cause financial burdens. (Brouthers K. D., Brouthers L.E., Wilkinson 1995)

In the evaluation of potential partners, the company can also consider the impact of the partner on firm's opportunity and threat in the external environment, firm's internal strengths and weaknesses, strategic decision.

For what concerns the impact on firm's opportunity and threat in the external environment, the company need to analyse if there is the possibility of a change in the bargaining power of costumers or suppliers; a threat of entry; a change in position in the market; a change in the availability of goods or a threat of substitutes. In the impact on firm's internal strengths and weaknesses, a company has to evaluate if there is an enhancement of strength; an overcome of weaknesses; a competitive advantage; an enhancement of core capabilities; a change in financial strengths or weaknesses. In the impact on strategic decision, a company has to assess if the alliance fit with the statement of strategic intent; if it helps to close any resource or technology gap; if the objectives could change over time. (Schilling 2020, p.188-190)

1.7 MONITOR OF PARTNER

An important aspect to determine for building a successful alliance is the mechanism of control and governance. There are three different types of governance: equity ownership, alliance contracts, self-enforcing governance.

Equity ownership is a mechanism in which one company acquires an equity stake in the other one, or partners create a new independent company in which both have a stake. The benefits of this type of mechanism are various. Firstly, it helps to align mutual interests, because, by owning shared equity, the concerns for investment decrease the possibility of opportunistic behaviour. Secondly, it facilitates the daily monitoring of the alliance, as it fosters a sense of ownership and involvement in the project. Finally, each of the partners receives a return on investment and this leads to enhance cooperation. (Kale, Singh 2009)

The second mechanism concerns the alliance contract, in which the rights and obligations of both partners within the collaboration are clearly defined, and also exhibit the legal remedies in case of breach of the agreement. The contract deal with several aspects, such as: the contribution of each party to the alliance in form of financial resources, services, plants, intellectual property; the level of control attributed to each partner, such as the right to bring in new participants or change the terms of the agreement; timing and ways of sharing what is generated by the alliance. (Kale, Singh 2009)

The third mechanism concerns self-enforcing governance, that is based on goodwill, trust and reputation of the parties, which emerge over time through cooperation. This type of mechanism helps to reduce the transaction costs in various ways: the contracting costs are reduced, since the partners expect that they will not use opportunistic behaviours; monitoring costs are reduced, because there is no need for monitoring by external parties; adaptation costs are reduced, because partners can be flexible to changes in the external environment. In addition, self-enforcing governance facilitates cooperation, knowledge sharing, and if collaboration is based on resource dependency, this mechanism becomes an efficient way to control and monitor partner behaviour. (Kale, Singh 2009)

1.8 MANAGEMENT OF STRATEGIC ALLIANCE UNDER UNCERTAINTY

Before starting to expose the topic covered in the paragraph, a brief introduction is necessary. The following paragraph will describe how it is possible to manage a strategic alliance relationship under uncertainty. This is particularly important later when the case study will be presented, which refers to a strategic alliance between buyer and supplier under uncertainty.

The collaboration must provide for a contract between the parties that leads to the fulfilment of three basic requirements:

- induce transaction-specific investment by both parties;
- establish a framework for iterative collaboration and adaptation of the obligations of the parties under conditions of continuous uncertainty (coordination cascade);

- limit the risk of opportunistic behaviour. (Gilson, Sabel, Scott 2009)

The formal contract alone cannot guarantee knowledge of the cooperating parties, nor the confidence in the future cooperative behaviour of the parties. These are essential elements to ensure the success of cooperation, so it becomes necessary to adopt certain mechanisms. The following discussion will be divided into three parts: the first section will analyse the duration of the collaboration contracts and the birth of opportunistic behaviours; the second section describes the various mechanisms used to prevent these opportunistic behaviours; finally, the third section will discuss the interaction between formal and informal mechanisms. (Gilson, Sabel, Scott 2009)

Duration of contact

The structure of cooperation contracts to prevent opportunism differs according to duration, that is whether they are long-term or are intended only for the development of a single project.

In the case of long-term contracts, opportunistic behaviour arises from the same collaboration. The uncertainty in this type of contract makes it impossible the ex-ante allocation of ex-post decision power, through assigning to one party options to take action like termination. Moreover, as each party comes into possession of the information about the other's abilities, the risk of giving priority to their own interests at the expense of the common good increases. This risk is particularly likely due to the fact that the parties make specific investments in the cooperation and they are not always symmetrical, and therefore each party is vulnerable at different times during the cooperation period. In order for the alliance to be successful, it is necessary to rely on informal mechanisms to limit the emergence of opportunistic behaviours during the collaboration. (Gilson, Sabel, Scott 2009)

On the other hand, as regards contracts involving the development of a single project, the informal mechanisms operating during this period discourage the emergence of opportunistic behaviour, in particular, the appropriation of jointly produced information for private purposes acts as a deterrent. Opportunistic behaviour, however, could arise once the cooperative phase of the project is over. For example, the division of benefits from previous cooperation remains at risk. (Gilson, Sabel, Scott 2009)

That is why in both cases there is a need for mechanisms that prevent this problem from arising.

Mechanisms to prevent opportunistic behaviour

The mechanisms used in collaboration contracts vary according to the needs of the parties, but these can be divided into three phases of collaboration:

- the collaborative/learning phase;
- the ongoing collaboration phase;
- the end stage phase.

The collaborative/learning phase is defined as the initial period, in which both parties involved are required to invest in producing information. At this stage, mechanisms that help prevent opportunistic behaviours can be divided into two groups:

- mechanisms to facilitate iterative investments in information;
- mechanisms to improve the quality of the information produced, such as contract referee. (Gilson, Sabel, Scott 2009)

In the case of mechanisms that facilitate iterative investment in information, these are important as they clearly spell out what are the processes for collaboration and dispute resolution. And thanks to these, during the collaboration, the production of information from each of the contracting parties is supported by the formally specified collaboration and dispute resolution processes. In this way, the collaboration contract is seen by the parties as a tool to organize learning and continuous collaboration, with the investment, which is made in the relationship, protected thanks to a growing mutual dependence. (Gilson, Sabel, Scott 2009)

The contract referee mechanism is very important as it allows to mitigate the risk of misinterpreting the behaviours of the parties involved in the collaboration. In fact, collaborations that rely exclusively on informal enforcement can fail, due to the fact that this type of enforcement requires that both parties are able to observe and correctly perceive the behaviour of the other. But the signals, sometimes, could be misunderstood, and therefore, in these situations, reciprocity becomes a less effective mechanism for enforcement. The mechanism of contract referee is based essentially on three key elements: the commitment to share and exchange information during the collaboration; the allocation of decision-making powers to a joint project management team, subject to an unanimity rule; the appointment of referees representing each company and instructed to resolve disputes. This type of mechanism offers several advantages. First, the referee may provide information regarding cooperation that the parties cannot obtain directly. In addition, it can clear up misunderstandings when they arise, preventing parties from identifying each other's behaviour as opportunistic when it is not, or remedy the dispute when opportunistic behaviour has actually occurred. Moreover, the referee acquires a disciplinary function, since he is not in favour of any of the parties. Secondly, the use of a project management team regulates shirking. Third, the information that are produced are symmetrical, about the value created by the collaboration and the preferences for mutual collaboration. And as long as the parts are symmetrical, the decisions produced will be efficient. (Gilson, Sabel, Scott 2009)

The second phase regards the ongoing collaboration, and in this circumstance the opportunistic behaviours tend to increase because of the relation-specific investments in which the parts incur. In this regard, the mechanisms that have just been analysed play the important role of mitigating this problem in two different ways:

- building switching costs;
- screening out naturally opportunistic counterparties. (Gilson, Sabel, Scott 2009)

First, switching costs can be defined as the costs arising from the change of the counterparty to another. During the initial phase of collaboration and learning, switching costs are created, such as information costs. Information costs are the cost of learning the other party's behaviour, in other words, if the company is willing to cooperate and act in good faith. This creates barriers to opportunistic behaviours, because seeking a replacement means incurring in new costs for learning and cost of consuming time. The type of switching costs that arises from the collaboration structured in this way has two fundamental features. The first consists in the fact that the switching costs are created by the effort of both parties, unlike those created by a unilateral effort with the aim of making difficult the exit from the collaboration. Indeed, the parties invest in relation-specific information concerning each other's capabilities, investments that would be lost if the relationship terminated and that would have to be duplicated with any new company. The second is the fact that investments are made gradually during the period, and that is why they are the result of the efforts in the cooperation. So, switching costs become more efficient as a tool to combat opportunism, as the relationship continues over time, with the parties will increase their knowledge of each other. Another form of switching costs that can arise from collaboration is that of reputational damage. By reputational damage it means the fact that companies, with which in the future cooperation will be sought, will be sceptical of those who in their history of past relationships adopted an opportunistic behaviour. However, this is seen as a type of switching cost that depends essentially on the context, since the reputational damage must also be observable to other companies outside the collaboration, and this fact is not always taken for granted. In addition, even if the failure of the collaboration is visible, it would be difficult to understand what the real reason is. (Gilson, Sabel, Scott 2009)

It then becomes of fundamental importance to be able to distinguish between the parties who will prove to be a co-operator, from those who will behave in an opportunistic way. The willingness to enter into a cooperation contract is not a reliable signal to prove that a company will be a co-operator. In this regard, contracts include mechanisms that allow to generate information about the feasibility of the project, and scope of the collaboration help to build cooperation between the parties already from the first phase. In fact, from the very first moment it is possible to begin to observe what is the behaviours of the parties with regard to the resolution of disputes, and in this way to build reciprocity, which will allow to gradually lock the parties in the relationship. The governance that is created in this type of contract has two different functions. The first concerns the fact that it allows to gain knowledge about the behavioural trends of the other parties, thanks to the sharing of information from the initial stage. At this point the risk could be that the parties decide to adopt a collaborative behaviour only in the first phase, and then adopt opportunism when the investments in the relationship will be greater. But this type of governance always intervenes to solve the risk, and this concerns the second function. In fact, in this case the parties are not only subject to observation, but also to demonstrate an effort and spend time to execute a portion of the agreement. (Gilson, Sabel, Scott 2009)

To summarize, a contract operating under conditions of uncertainty will be doomed to failure if it is not able to limit the likelihood of opportunistic behaviour. This function is well performed from the birth for both parties of switching cost. The first phase of the collaboration is of fundamental importance for this purpose, in fact, the screening and learning process, regarding the tendency of the parties to the opportunistic behaviours, becomes expensive in case it must be repeated with a new partner. Moreover, the collaborative mechanism that produces the information necessary for the success of the collaboration allows to continue the relationship also in the successive phases.

The last phase is the end stage. It is important to discourage opportunism at the time of the division of earnings, when the collaboration is coming to an end. In this case, the mechanisms described above to limit opportunistic behaviours take a different form. Indeed, what has been described previously worked because the information provided in the relationship by both parties are symmetrical, but once the period of collaboration is over, issues related to opportunism can re-emerge. In such a situation, the collaboration contract should complement the function of switching costs in the cooperative phase with explicit provisions, that assign specific decision-making powers to each party during the non-cooperative phase. The problem, however, cannot be solved simply by linking the gains of each party to the results obtained, since it is not possible to predict ex-ante all the possible states of the world in which cooperation will evolve. The solution seems to be to use contracts that provide nested options, which prevent opportunistic renegotiations in the end stage. (Gilson, Sabel, Scott 2009)

Interaction between explicit and implicit terms in contracts

The consequences of contracts containing certain implicit terms (self-enforcing) and other explicit terms (legal enforcing) depend on the possible effects of the two application alternatives on each other. Starting from the implicit mechanisms, in this case sanctions are imposed ex-post and implicitly, without risking that the party that acted with the right conduct would suffer damage, caused by announcing in advance that there would be a sanction for the party that acted opportunistically. In addition, reciprocation leads to a state in which engage in a cooperative relationship leads to develop a company preference for increasingly cooperative behaviours. Studies have shown that, even in the absence of legal enforcement, reciprocity alone generates a high level of cooperation, and when a contract also includes legal enforcement, reciprocity decreases. But more recent studies have shown that, in cooperation between parties that has an undefined duration, legal enforcement can support collaboration, but only when it is limited to a verifiable dimension. Therefore, the explicit terms of the contract support the implicit mechanisms, but only in the event that "explicit mechanisms are designed to legally enforce only the verifiable terms of a contract, and where the parties believe in the prospect of an ongoing relationship, the evidence suggests that explicit mechanisms designed to deter opportunism at the end stage of collaborative contracts may reinforce the patterns of trust and reciprocity, thereby enabling the parties better to enforce themselves the non-verifiable portions of the relationship". (Gilson, Sabel, Scott 2009)

1.9 INSTABILITY OF STRATEGIC ALLIANCE

"Alliance instabilities refer to major changes or dissolutions of alliances that are unplanned from the perspective of one or more partner". (Das, Teng 2000)

Within the literature it is possible to identify various explanations regarding the causes of the instability of alliances.

The fist approach comes from the relational contracting theory by Macneil, that highlights the fact that trust between partners is a fundamental point in the relationship. Linked to this, the transaction cost theory by Williamson is focused on the opportunistic behaviour, that can compromise the alliance. In fact, companies are naturally inclined to pursue their own interests at the expense of those of the partner, and the cost to limit opportunistic attitudes is high, given the difficulty of controlling the partner. (Das, Teng 2000)

A second approach is given by the game theory by Axelrod, because it is explained that the situation in strategic alliances is similar to that of the prisoner's dilemma. In fact, the partners, not being sure of the intentions of others, decide not to cooperate. The pay-off that is obtained by not collaborating is greater than that obtainable by collaborating, and this leads the alliance to failure. (Das, Teng 2000)

Then, a third approach is present in the resource dependence theory by Pfeffer and Salancik, linked to bargaining power perspective by Bacharach and Lawler. According to the resource dependence theory, a company, in order to realize its own objectives in the alliance, relies on determined resources of partners, diminishing therefore its own dependence on the external environment. However, increase in the dependency on the partner and lack of power balance lead to instability. In fact, according to the bargaining power perspective, the value of the resources owned by each company determines the bargaining power in the negotiations. (Das, Teng 2000)

A fourth approach is that of the agency theory by Jensen and Meckling, in which alliances can benefit from teamwork. At the same time, however, it is specified that managers, in these types of relationships, tend to make decisions that benefit themselves rather than the company they work for. Often managers make choices aimed at increasing their pay, or to control the risk of their employment, and this leads to instability. (Das, Teng 2000)

Finally, a fifth approach can be found in the strategic behaviour theory by Porter, according to which companies develop strategies that allow them to gain a competitive advantage over competitors. Strategic alliances allow access to a better competitive position, thanks to some objectives such as access to new technologies or markets, creation of economies of scale, sharing of risk. Nevertheless, it is pointed out that there are often excessive expectations of objectives that are impossible to achieve, or, in other cases, companies are not patient enough to wait for the goals to be achieved. In this situation, instability in the alliance results from imperfect strategic planning and implementation. (Das, Teng 2000)

Although all these theories point to features of strategic alliances that can lead to their instability, this does not seem to be enough since they are fragmented and incomplete. For this reason, Das and Teng (2000) have identified a new approach, which is based on the fact that within the alliance conflicts develop, and this is what explains the instability that is created. And, to create a successful alliance, it is necessary to balance these opposing forces. There are three pairs of contrasting forces: cooperation vs competition, rigidity vs flexibility, short-term vs long-term orientation. (Das, Teng 2000)

Cooperation vs competition: cooperation is defined as acting to pursue the mutual interest, while competition is the will to pursue their own interests at the expense of others. Much emphasis is placed on the role of cooperation within alliances, because it leads to the achievement of common goals through the sharing of resources. But it does not mean that competition does not exist, and that competition leads to opportunistic behaviour from the company which only want to achieve its own interest. Although the two forces are seen in terms of paradox, both are necessary for the success of the alliance. In fact, cooperation ensures that the goals of the alliance are best achieved from the partners, while the competition is useful to preserve their competitive advantages from partners due to inattention. Only by keeping these two forces in balance the success of the alliance can be assured. (Das, Teng 2000)

Rigidity vs flexibility: rigidity refers to the characteristics of mutual dependence with another company, while flexibility help to increases the ability of partners to adapt without being hindered by rigid provisions. Rigidity is important because it leads the company to align its interests with those of the partner and to discourage opportunistic behaviour, while flexibility helps to control risk, adapt to changing situations and use limited resources. The maintenance of a balance between these two forces is essential for the existence of an alliance. In fact, when too much importance is given to flexibility, the alliance tends to evolve into a new system that requires little control, and in this way the bond between the two partners weakens, making the alliance vulnerable. On the contrary, if too much emphasis is placed on rigidity, there will be a resistance of partners to adapting to change. (Das, Teng 2000)

Short-term vs long-term orientation: short-term orientation is preferable in alliances that aim to achieve quick and tangible results, long-term one aims to achieve results to be built with commitment and patience. Within an alliance these two forces are often in conflict, since the partners may have defined different orientation times, and also because the duration of alliances is often ambiguous. The advantages of a short-term-oriented alliance are, firstly, that an alliance is known to be a risky operation, so it can be more beneficial to get results quickly. Secondly, a short alliance prevents this becoming a burden with time for partners. Long-term-oriented alliances also have advantages, in fact, specific investments in the alliance are only possible when the duration of contracts is long enough. This because the fact of knowing that the duration will be long, aligns partners and discourages opportunistic behaviour. Thus, there must be a balance of these two opposing forces, because a strategy that reflects only one temporal orientation is doomed to fail. When short-term orientation prevails, the partners are not concerned about the sustainability of the alliance but only about exploiting the resources. On the contrary, when long-term orientation prevails, it becomes difficult to plan for such a distant future in an ever-changing environment. (Das, Teng 2000)

1.10 FACTORS OF SUCCESS AND FAILURE

In conclusion it can summarize which are on one hand the key factors for failure, and on the other hand those for success.

Masoud, Buzovich and Vladimirova (2020) propose the following as the main reasons for failure:

- "a wrong choice of partner, incorrect ideas about his abilities and opportunities;
- the complexity of a clear definition of the association goals, the different strategic goals of the parties, their contradictions/conflicts, the change of the strategic goals of one of the partners;
- unrealistic market expectations;
- difficulties in management and coordination of the interests of the parties involved, changes in the corporate governance of one of the companies;
- problems of criteria selection for the effectiveness evaluation of the alliance and its financial activities results summarizing, the complexity of control;
- inability to deal with different management styles and corporate cultures, lack of knowledge about cultural national values, behaviour and governments, which leads to inadequate inter-partner communication, reduces the effectiveness of interaction and, moreover, is the most common cause of failures of the international strategic alliances;
- lack of trust between the participants, unwillingness of the employees of the merging company to reach mutual understanding and establish the effective interaction;
- possibility of a partner's failure of his obligations, opportunistic mood of one or more of the partners;
- mistakes and failures of one of the participants leading to serious damage to the image of the alliance as a whole;
- risk of leakage of information through employees of a partner firm;
- enticement by a partner of the company best employees being carriers of know-how; this can cause a weakening of the competitive potential". (Masoud, Buzovich, Vladimirova 2020)

The same authors, previously mentioned, identify the following as the factors leading to success:

- “complementary skills and knowledge of partners;
- minimal overlapping of partners’ markets;
- high level of autonomy, while maintaining strong leadership of the parent organization (if necessary);
- trust between partners involving cooperation not limited only with the stipulations included in the contractual arrangements;
- respect of the fact that both partners have different corporate cultures”. (Masoud, Buzovich, Vladimirova 2020)

2. THE SEMICONDUCTOR INDUSTRY

2.1 INDUSTRY ANALYSIS

Before starting to describe the semiconductor industry, it is useful to provide a definition of what they are.

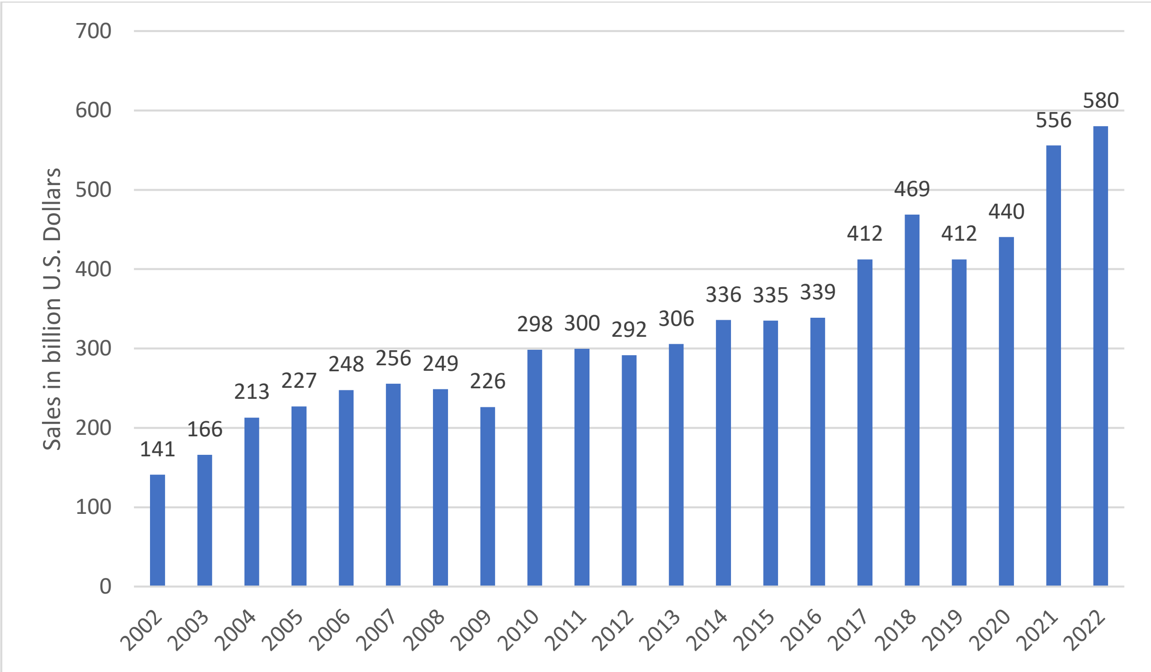
"Semiconductor devices, also known as 'chips', are the foundation of all modern electronics. A semiconductor is a material, typically silicon, whose ability to conduct electricity falls between a conductor (like copper) and an insulator (like glass). Its electrical properties can be changed by adding impurities, or by the application of electric fields, light or heat. Electronic components such as integrated circuits or ICs are a set of complexes, minute electronic circuits integrated into a piece of silicon (hence, 'chip'). These chips consist of thousands to billions of active and passive circuitries such as transistors, that control the flow of electricity for amplification, switching, storing, and mathematical operations. Importantly, they are readily manufacturable and economical at scale. Chips serve as the basis for all our modern technologies. They are our physical connection to the digital world, integral to the electronics that enable our daily existence and fuel cutting-edge technological advances in computing, wireless communications (5G), Internet of Things (IoT), quantum computing, and beyond". (Alam et al. 2022)

Size of the industry

As shown in Chart 1, in 2022 the global semiconductor market reached a value of $580 billion in sales. In fact, this is a sector of particular importance, since it accounts for about 0.5% of world GDP. Moreover, the semiconductor industry has a decisive role as part of the digital economy. (Casanova 2023)

Over the last twenty years, sales in the semiconductor sector have grown exponentially. In fact, it is possible to notice that in 2002 sales had a value of $141 billion, reaching then the current one of 2022, which is more than quadrupled. However, in the growth of this sector, it is possible to notice some moments of decline. These are visible between 2007 and 2009 due to the Great Recession, and then in 2019 with the COVID Recession. (Casanova 2023)

Chart 1: Global semiconductor industry market size from 2002 to 2022



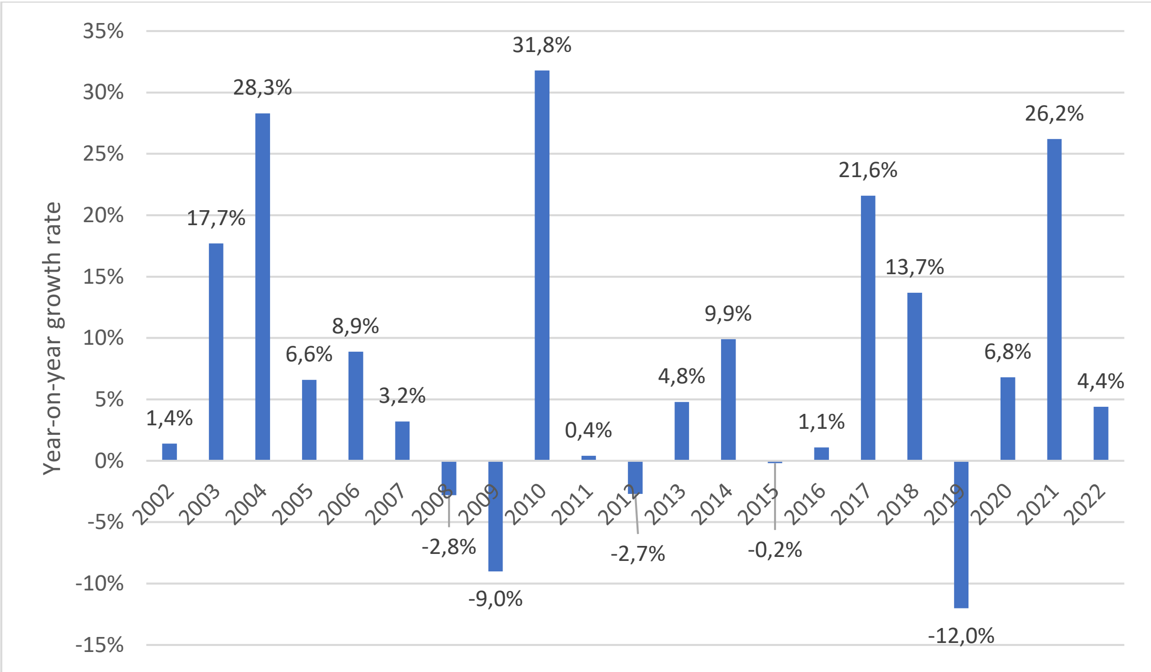
Source: Statista 2022a

In Chart 2, it is shown the growth rate of the sector year after year. Particularly significant, in a negative sense, are the values of 2009, which results in a growth of -9% from the previous year, and 2019 with a growth of -12%. These values, consistent with what has been said before, result in times of global crisis. Immediately after these two crises, however, there was a recovery, in particular it can be seen a growth of 32% in 2010, while a growth of 7% in 2020.

Focusing attention in recent years, it is possible to notice that, despite the harsh crisis of COVID and the negative growth of 2019, the industry has recovered immediately with an increase of 25% in 2021 from the previous year. (Casanova 2023)

However, 2022 did not experience such exponential growth due to some factors, such as increasing inflation, geopolitical unrest, and the persistent effects of the pandemic. Even so, all this has not prevented the growth of the sector. (Casanova 2023)

Chart 2: Global semiconductor industry revenue growth from 2002 to 2022

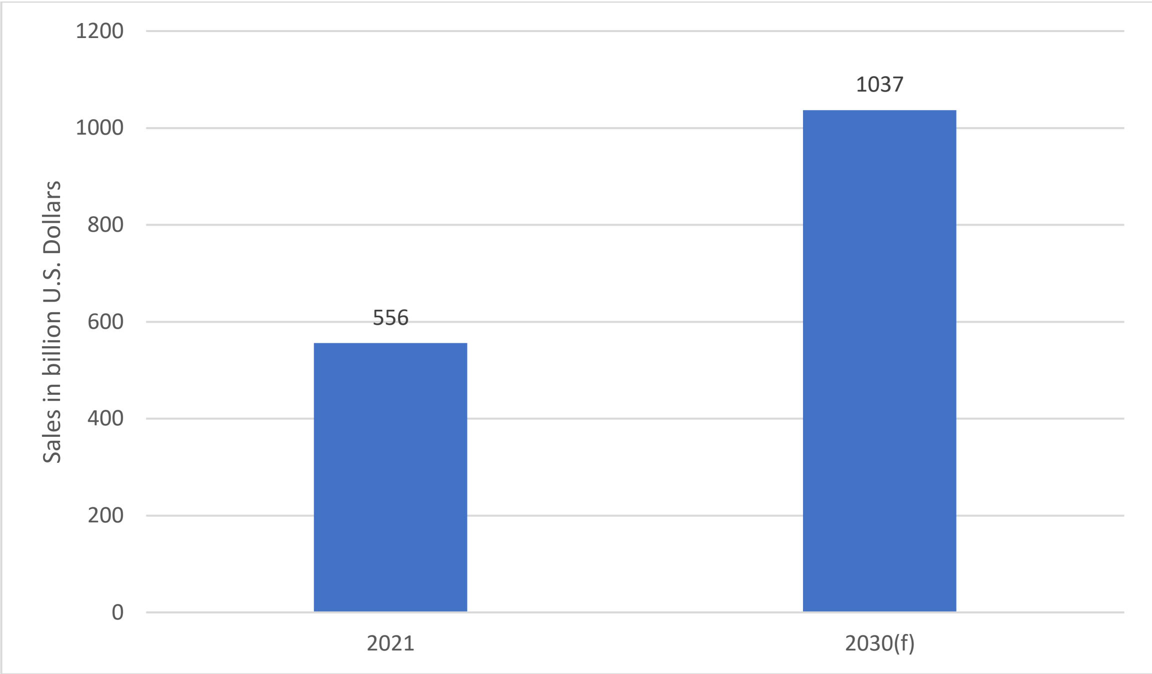


Source: Statista 2022b

As shown in Chart 3, the semiconductor industry is expected to continue to grow in the coming years, exceeding the value of $1 trillion in 2030.

Among the various applications of semiconductors, the one that will most lead to this result is expected to be that of automotive, with sales growth much higher than the industry average. Indeed, with increasing awareness of sustainability and governments wanting to stop selling fossil-fuel-powered vehicles, there will be a push towards electric vehicles. These require more use of semiconductors in their components, and consequently increase demand in this industry. (Wu 2023)

Chart 3: Global semiconductor industry sales growth 2021-2030



Source: Wu 2023

Types of products

The semiconductor industry is divided into the production of different types of semiconductors, which are grouped into several segments. In addition, these segments of semiconductors can be divided into two categories: general purpose chips and application specific chips. General purpose chips are commodity like in nature and include memory, analog, logic, discrete, micro components, optoelectronics, and non-optical sensors. Application specific chips (ASICs) are used for specific uses. (Alam et al. 2022)

LOGIC SEGMENT: logic semiconductors are used to process information to help electronic devices complete their tasks. The sub-segments of this type of semiconductor are: display drivers; field programmable gate array (FPGAs); programmable logic devices (PLDs). (Alam et al. 2022)

MEMORY SEGMENT: memory semiconductors are used for digital data storage. They are employed in any electronics assembly that uses computer processing technology. The sub-segments of this type of semiconductor are: dynamic random-access memory (DRAM); NAND Flash; emerging memory. (Alam et al. 2022)

ANALOG SEGMENT: analog semiconductors are electronic components that support many functions. They can generate a signal or transform signal characteristics, such as amplitude, phase, and frequency. The sub-segments of this type of semiconductor are: data converters/switches/multiplexers; voltage regulators/reference. (Alam et al. 2022)

OPTOELECTRONICS SEGMENT: optoelectronics semiconductors are used for the procurement, detection and control of light. They are electronic devices that convert electricity into photon signals for various purposes. The sub-segments of this type of semiconductor are: CCD image sensors; CMOS image sensors; LEDs; photosensors; couplers; laser diodes. (Alam et al. 2022)

DISCRETE SEGMENT: discrete semiconductors are devices that are specified to perform elementary electronic functions, that cannot be divided up into other functions. The sub-segments of this type of semiconductor are: transistors; diodes; thyristors. (Alam et al. 2022)

ASIC (application specific integrated circuit) SEGMENT: ASIC semiconductors are designed for a specific end application for use by a single customer. The sub-segments of this type of semiconductor are: discrete application/multimedia processor; discrete cellular baseband; discrete GPUs; integrated baseband/application processors; power management; wireless connectivity (NFC, Wi-Fi, Bluetooth, GPS, combo); wired connectivity; RF front-end and transceivers. (Alam et al. 2022)

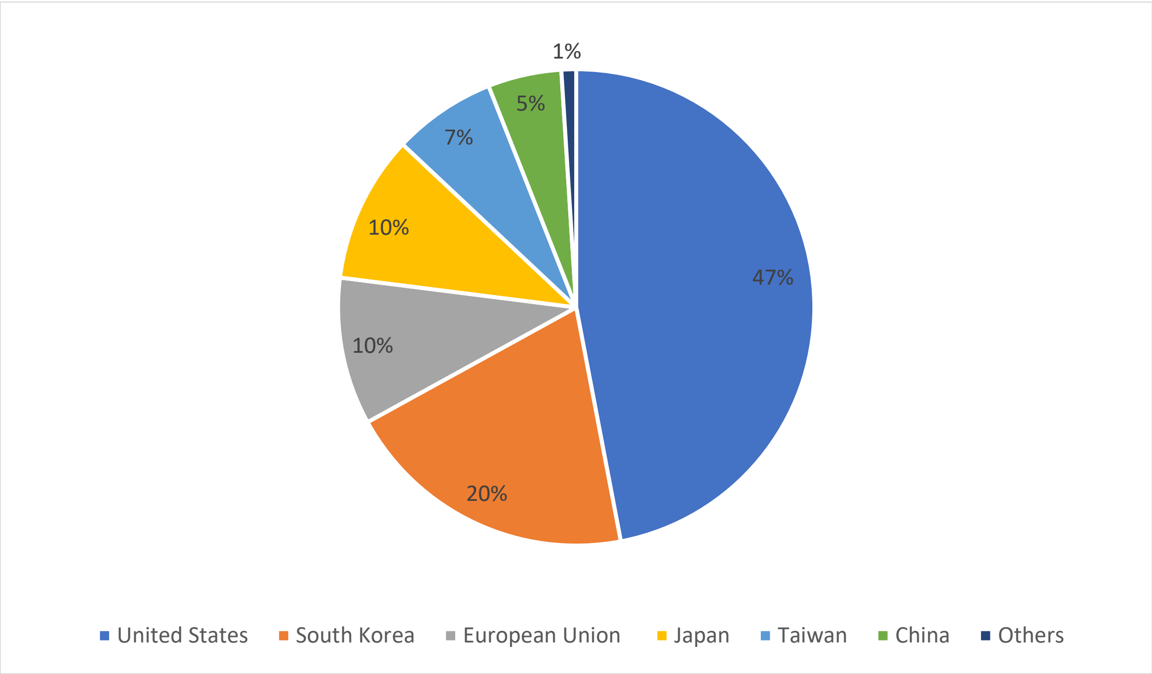
NON-OPTICAL SENSOR SEGMENT: non-optical sensor semiconductors are devices that are used to measure or respond to physical changes in the environment and to convert signals into electrical signals. The sub-segments of this type of semiconductor are: environmental, digital, inertial and magnetic sensors; MEMS microphones. (Alam et al. 2022)

MICRO COMPONENTS SEGMENT: micro components semiconductors are device that can be programmed to perform specific tasks and create an essential part of any electronic device. The sub-segments of this type of semiconductor are: digital signal processors (DSP); microcontrollers (MCU); microprocessors (MPU). (Alam et al. 2022)

Supply side

Chart 4 show the market share of the global semiconductor industry by country in 2020. The industry is dominated by the United States, which have 47% of market share. More specifically, three-quarters of this market is dominated by IDM companies, such as Intel and Micron, while the remaining 25% is made up of fabless companies, such as Qualcomm and Nvidia. Then follow South Korea with 20%, and Japan, that alone reaches a value of 10%. In this case, the market is dominated by IDM companies for more than 90%. Taiwan and China account for 7% and 5% respectively, of the global market. Despite being considered the main locations of the foundry, about 90% of the revenue is the result of fabless companies. Finally, there is also the European Union, that globally reaches 10% of market share. (Alam et al. 2022)

Chart 4: Global semiconductor industry market share by country in 2020



Source: Statista 2021

Among the main players in the supply side, the top 10 companies of 2022 based on revenue are the following.

TAIWAN SEMICONDUCTOR MANUFACTURING CO. LTD. (TSMC): with a revenue of $72 billion, it is the largest foundry company in the world, manufacturing products that then will be applied in many end markets, including high performance computing, smartphones, Internet of Things (IoT), automotive and digital consumer electronics. The headquarter is located in Taiwan. (Reiff 2023)

INTEL CORP. (INTC): it is the leading manufacturer in the United States, and belongs to the category of IDM companies. The company manufactures motherboard chipsets, network interface controllers and integrated circuits. Its market is divided into three segments: Client Computing Group segment, which deals with personal computers; Data Center Group segment, which deals with corporate servers; Internet of Things (IoT) solutions segment. Headquartered in the United States, the 2022 revenue reached $70 billion. (Reiff 2023)

QUALCOMM INC. (QCOM): the firm is a leading company in the semiconductor and telecommunications industries, and it is a fabless company. It deals with the design and marketing of products and services of wireless communication. The headquarter is located in the United States, and the revenue for 2022 was $42 billion. (Reiff 2023)

BROADCOM INC. (AVGO): it is a fabless company that provides digital and analog semiconductors, and software infrastructures for networking, telecommunications and data centres. In 2022, it recorded revenue for $33 billion, and the headquarter is located in the United States. (Reiff 2023)

MICRON TECHNOLOGY INC. (MU): this company is part of the IDM category, and deals with producing different types of semiconductors, more precisely in the segment of memory chips. Its products are then used in computers, consumer electronics, automobiles, communications, and servers. Revenue for 2022 was $31 billion, and it is a US-based company. (Reiff 2023)

NVIDIA CORP. (NVDA): it is a fabless company, world leader in the computing sector, dealing mainly with the development of graphic processors for personal computers and corporate servers. The headquarter is located in the United States, and in 2022 it reached a value of $29 billion in revenue. (Reiff 2023)

APPLIED MATERIALS INC. (AMAT): it is a leading provider of semiconductor equipment and liquid crystal display (LCD) screens. Headquartered in the United States, in 2022 it reached $26 billion in revenue. (Reiff 2023)

ASE TECHNOLOGY HOLDING CO. LTD. (ASX): the company deals with assembly, packaging, and testing services in the semiconductor industry. It is a company headquartered in Taiwan, and the revenue reached in 2022 was $23 billion. (Reiff 2023)

ADVANCED MICRO DEVICES (AMD): this firm is part of the fabless companies, and deals with the design and marketing of microprocessors, graphics processing units (GPUs), and other computer hardware components. The sector in which it operates is that of personal computers and servers, and its products are applied to desktop and laptop computers, game consoles, and cloud and enterprise servers. The company is headquartered in the United States, and in 2022 it had revenue for $23 billion. (Reiff 2023)

ASML HOLDING N.V. (ASML): it is a leading provider of semiconductor manufacturing equipment. More precisely, it specializes in the development and manufacture of lithography machines used to produce chips. The company is based in the Netherlands, and closed 2022 with a revenue of $21 billion. (Reiff 2023)

Demand side

Chart 5 shows how the global semiconductor market is divided according to different applications.

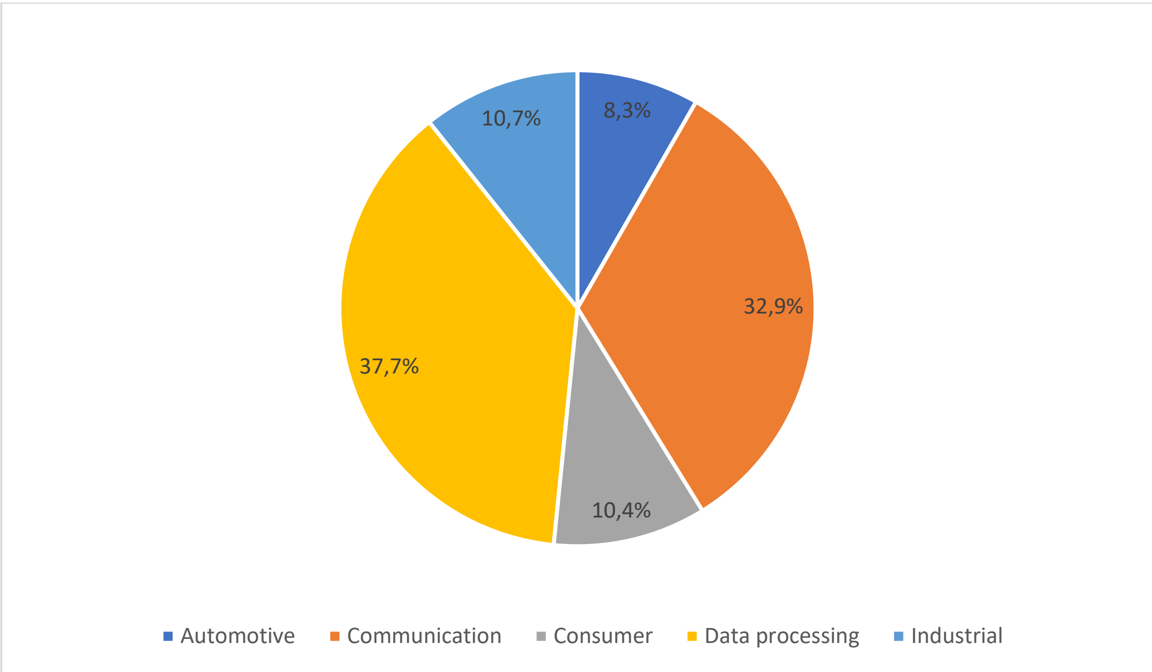
The sector with the highest demand for semiconductors is data processing, with a value of 37.7%. Data processing includes computers, laptops and peripheral equipment. With the advent of the COVID pandemic this segment peaked, because students and workers were forced to move to study and work from home, and, due to do this, they needed to equip themselves with computers and laptops. In fact, in 2020 there was a growth of 13% of this segment, but a slight decrease is expected in the following years. (Alam et al. 2022)

The communication segment is also of great importance, with a value of 32.9%. This segment includes products such as cell phones, wireless infrastructure, and modems. The importance of this segment comes from increased connectivity and increased availability of mobile devices in the world. Although the demand for semiconductors has slowed due to the maturing of 4G infrastructure, the push towards new 5G technology will lead to a new rise in demand for semiconductors. (Alam et al. 2022)

The automotive segment recorded a value of 8.3%. Although it is the smallest segment for semiconductor demand in 2020, this is set to grow a lot in the coming years, thanks to the fact that electric cars are becoming increasingly popular. These require a higher and more sophisticated number of semiconductors, opening up new growth opportunities for this segment. (Alam et al. 2022)

Finally, the consumer segment reaches a value of 10.4%, and includes for example TVs and digital set-top boxes. While the industrial segment, with a value of 10.7%, includes automation, healthcare and security. (Alam et al. 2022)

Chart 5: Global semiconductor industry market size by application in 2020



Source: Alam et al. 2022

The companies that were the main buyers of semiconductors in 2022 are the following, sorted by the value of the expense. As shown in the table 1, Apple ranks first with an expense of $67,056 million. Despite this, the expense is down from the previous year, due to the fact that the company is trying to bring part of the semiconductor production in-house. Second place went to Samsung Electronics, which spent $46,056 million. The expenditure compared to the previous year is higher, thanks to the fact that the company is gaining a greater market share in the smartphone sector. Finally, the result achieved by Sony is worth noting, with an increase in expenditure compared to the previous year of 16.5%. This is mainly due to increasing consumer interest in gaming consoles. (Keen 2023)

Table 1: Top 10 companies by semiconductor spending in 2022 in global semiconductor industry

2022 Rank	2021 Rank	Company	2022 Spending	2021 Spending	2021-2022 Growth (%)
1	1	Apple	67,056	68,851	-2.6
2	2	Samsung Electronics	46,065	45,091	2.2
3	3	Lenovo	21,031	25,410	-17.2
4	5	Dell Technologies	18,304	20,977	-12.7
5	4	BBK Electronics	18,082	21,810	-17.1
6	6	Xiaomi	14,602	16,465	-11.3
7	7	Huawei	12,075	14,977	-19.4
8	8	HP Inc.	11,291	13,927	-18.9
9	10	Sony	7,975	6,847	16.5
10	9	Hon Hai Precision	7,531	8,028	-6.2

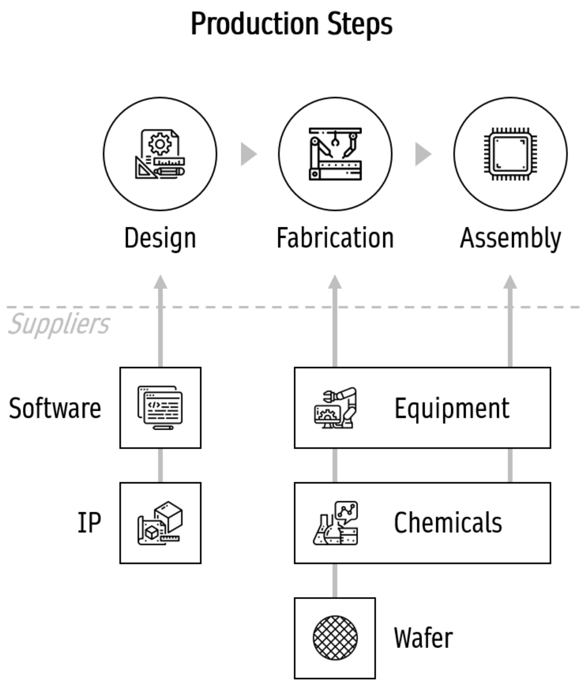
Source: Keen 2023

2.2 STAGES IN SEMICONDUCTOR VALUE CHAIN

As shown in Figure 1, within the semiconductor value chain there are three fundamental steps: design, fabrication, assembly. Each of these steps relies on specific input from suppliers. The design step depends on the supply of software and intellectual property; the fabrication step, also known as front-end manufacturing, from manufacturing equipment, chemicals and silicon wafers; the assembly step, also known as back-end manufacturing, from equipment and chemicals. (Kleinhans, Baisakova 2020)

Finally, it can be added a final step, regarding the end product integration. In this step, chips are integrated by electronics and equipment manufacturers to create end products for consumers. Subsequently, end products will be shipped to companies, retailers, and consumers worldwide. (Alam et al. 2022)

Figure 1: Global semiconductor value chain



Source: (Kleinhans, Baisakova 2020)

DESIGN STAGE

Intellectual property (IP)

In the segment of semiconductor IP, the companies are involved in the development and subsequent licensing of semiconductors IP. The IP of a semiconductor consists of any specification, source code, or other information necessary for the production of a given semiconductor. These IPs can be entire processor cores or smaller IP blocks for "standard" functionality. The role of these companies is of particular importance for the entire design process, as they support chip designers and speed up the market entry of their offer. There are two types of IP: soft and hard. Soft IPs are those that can be modified by chip designers at the functional level, while hard IPs are those that cannot be changed. (Alam et al. 2022)

Key companies in this area include: ARM Holdings (UK), Synopsys (USA), Cadence (USA), Imagination Technologies (UK), Ceva (USA), SST (USA), VeriSilicon (China), Alphawave (Canada), Rambus (USA). (Alam et al. 2022)

Electronic design automation (EDA)

The companies, operating in this segment, are involved in the development of software tools that serve to help chip designers. Thanks to EDA it can be simulate functionality, integrate IP, optimize floorplan, and verify projects. This industry has become of particular importance over the years as chip design has become an increasingly complex process. In fact, chips can contain millions of logic gates and thousands of memory blocks, all of which are interconnected and placed accurately. The placement of these components affects the functionality, speed, power consumption, and cost of the chip. (Alam et al. 2022)

Nowadays, not only the design phase, but also the manufacturing depends on the EDA tools, in particular when they serve to improve the production processes to ensure producible chips and to reduce the prototyping time. Given the increasing complexity in chip design, many of the EDA companies have decided to acquire small companies that deal with IP semiconductors, so they can offer synergistic IP solutions with EDA software. (Alam et al. 2022)

An important aspect to consider is the fact that there is a concentrated market for EDA sellers. In fact, there is a concentration in the United States, which control 70% of the EDA market. This becomes a point in the value chain at risk of destruction, since trade measures, such as export bans, would cause serious damage. (Alam et al. 2022)

The main companies operating in this sector are: Cadence (USA), Synopsys (USA), Mentor Graphics (USA). (Alam et al. 2022)

Design

Design companies need to make decisions about certain chip components, such as size, memory and logic placement, and interconnections between transistors and gates of a chip. This step of the value chain is considered the most intensive in R&D, and the fundamental enabler of silicon technology. (Alam et al. 2022)

In this segment there are two different types of companies operating. They are integrated device manufacturers (IDM) and fabless. Fabless companies are those responsible for creating the design and specifications necessary for their chips, without having production assets. IDM companies not only deal with design, but also manufacture and sell their chips. In addition, it is important that design companies work closely with production, whether it is internal or external. This is because the chip design must adapt to a particular production process. (Alam et al. 2022)

The key companies in this sector on the fabless side are: Nvidia (USA), Broadcom (USA), Qualcomm (USA), AMD (USA), Xilinx (USA), Huawei Hisilicon (China), MediaTek (Taiwan). On the IDM side are: Samsung (South Korea), Sony (Japan), SK Hynix (South Korea), Kioxia (Japan), Renesas (Japan), NXP (Netherlands), Intel (USA), Analog Devices (USA), Texas Instruments (USA), Micron Technology (USA), Skyworks (USA), Electronics Infineon Technologies (Germany), STMicroelectronics (Swiss). (Alam et al. 2022)

FRONT-END MANUFACTURING STAGE

Equipment

Chip manufacturing companies (front-end and back-end manufacturing) rely largely on semiconductor manufacturing equipment (SME) firms. In fact, SME sellers often specialize in particular stages of the manufacturing process, and therefore chip manufacturers must combine equipment from different suppliers. There are many types of equipment, but the main ones refer to three categories: wafer fabrication and processing equipment; test equipment; assembly/packaging equipment. (Alam et al. 2022)

In turn, SME sellers rely on highly skilled suppliers, and this could become a problem, because for some components there is only one supplier worldwide. In fact, at this point in the value chain there is efficiency and great innovation, but also the risk of destruction due to trade measures, such as export bans or pandemics. (Alam et al. 2022)

The companies that play a key role in SME are: Applied Materials (USA), LAM Research (USA), KLA (USA), ASML (Netherlands), Tokyo Electron (Japan). (Alam et al. 2022)

Chemicals

Chip companies (front-end and back-end manufacturing) make extensive use of chemicals, gases, minerals, and high-purity materials. As with other supplies, in this case these companies work closely with those that produce chips and supply the equipment. Companies that supply these materials often do so not only in the electronics industry, but also in other industries such as pharmaceuticals or agriculture. So, at this point, the value chain is less exposed to shocks than other steps. (Kleinhans, Baisakova 2020)

Key companies in this sector are located worldwide, but especially in Japan, South Korea and Europe, and the main ones are: Shin-Etsu (Japan), Sumitomo Chemicals (Japan), Mitsui Chemicals (Japan), BASF (Germany), Linde (Ireland), KGaA (Germany), Taiwan Specialty Chemicals Corporation (Taiwan). (Kleinhans, Baisakova 2020)

Wafers

For chip production, raw wafers are one of the key elements, and they are produced in various sizes and materials. Silicon wafers are the standard for chips, but there are also other types, such as gallium arsenide, gallium nitride, and silicon carbide wafers. (Kleinhans, Baisakova 2020)

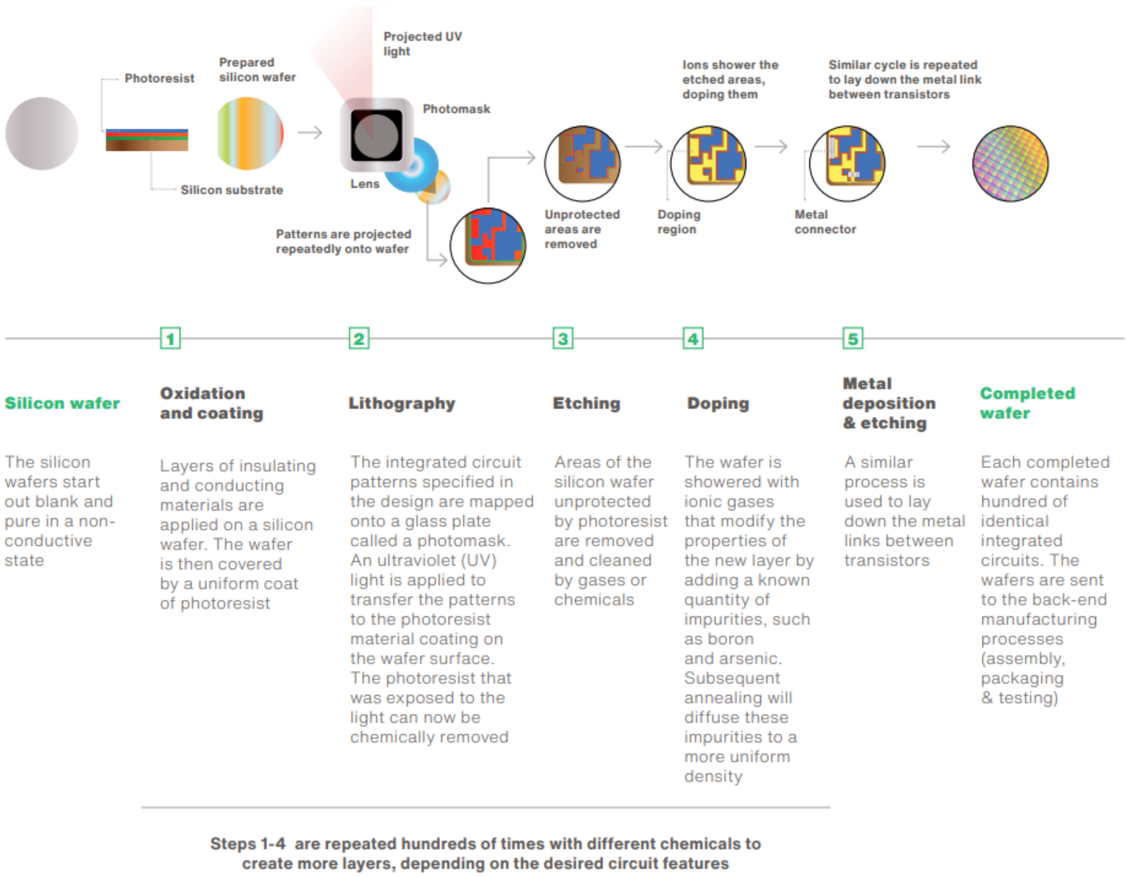
The wafer market is very concentrated, as only 5 companies control about 90% of the market share. Key companies in this area are: Shin-Etsu (Japan), Sumco (Japan), GlobalWafers (Taiwan), Siltronic (Germany), SK Siltron (South Korea). (Kleinhans, Baisakova 2020)

Fabrication

In this step, also called front-end manufacturing, companies are involved in processing raw silicon wafers. This is a very delicate step, as it requires that there is harmony between design, equipment and chemicals. In fact, once the chip design is completed, it is sent to the wafer fabrication plant for production, in which equipment and chemicals will be used to manufacture the chip design in a raw wafer. These fabrication plants may be owned by an IDM or a foundry. (Kleinhans, Baisakova 2020)

The manufacturing process of a completed wafer is shown in Figure 2.

Figure 2: Overview of the wafer fabrication process



Source: Varas et al. 2021

This value chain step is more capital-intensive than the others. Because of this, operating in this area means investing large amounts of capital. But this is not the only factor that counts, since it also requires a deep knowledge of the process, which is very complex. (Kleinhans, Baisakova 2020)

Most of the companies operating in this step are located in East Asia, with some clusters in the United States and Europe. The main players are, on the foundry side, TSMC (Taiwan), Samsung (South Korea), UMC (Taiwan), SMIC (China), GlobalFoundries (USA); on the IDM side, Intel (USA), Micron Technology (USA), NXP (Netherlands), Texas Instruments (USA), Neon Technologies (Germany). (Kleinhans, Baisakova 2020)

BACK-END MANUFACTURING STAGE

Assembly

After completing the front-end manufacturing in fabrication plants, there is the stage of back-end manufacturing. At this point the wafers are shipped to outsourced factories, which deal with packaging, assembling and testing the chips. The companies operating in this segment are defined OSAT (Outsourced Semiconductor Assembly & Test), which rely on the supply of equipment and chemicals, although in a lesser way than the companies of the front-end manufacturing stage, in fact it is a labour-intensive sector. (Alam et al. 2022)

An important fact to notice is that rising costs in the semiconductor value chain are leading many companies to bring in-house packaging, assembly and testing capacity to minimize supply chain costs and bottlenecks. (Alam et al. 2022)

The main companies in this step are: Amkor Technology (USA), Teradyne (USA), JCET (China), ASE Group (Taiwan), Powertech (Taiwan). Most of the companies operating in this sector are located in low-cost locations, such as Malaysia, Vietnam, China, and Taiwan. (Alam et al. 2022)

END PRODUCT INTEGRATION

Original Equipment Manufacturers (OEMs)

OEMs are companies that design and ship the final product to the consumer, and in the final product the semiconductor chip is integrated. In general, OEM companies design the product in-house, and supply chips from IDM or fabless companies. In the last period, however, it has been seen that the major OEMs have started to deal internally with the design of the chip, and to rely only for the part of manufactory to the foundries. (Alam et al. 2022)

These companies are the ones that have the closest relationship with end consumers, and therefore their products are designed to meet customers' needs. For this reason, more and more OEMs are interested in taking care of the chip design internally, in order to make it more tailored and customized for the characteristics of their end consumers. In addition, through vertical integration, OEMs have the know-how to venture new areas of semiconductor chip application. (Alam et al. 2022)

The main players in this step are: Apple (USA), Samsung (South Korea), Huawei (China), Lenovo (Hong Kong), Dell (USA), HP (USA). (Alam et al. 2022)

Electronics Manufacturing Services (EMS)

EMSs have become of particular importance since the ‘90s, when OEMs began to rely on them to reduce the risks and costs of manufacturing. Subsequently, OEMs have expanded their reliance on EMS companies, including services such as demand forecasting, supplier management, inventory management, materials procurement, outgoing logistics, delivery, warranty repair, and customer service. An advantage, that regards the increasing dependence on the EMSs, is the fact that through this mechanism the OEM companies can reach scalability of the volumes, mass personalization, reduction of the time-to-market, efficiency of the supply chain and the logistics. (Alam et al. 2022)

Most of the companies operating in this sector are located in Asia, as this region has an advantage affects some aspects, such as low overhead, low labour costs, and operational success in the production of low-margin and high-volume goods. Despite this, in recent years EMSs have begun to locate themselves in other regions of the world, to minimize transport costs and to be closer to OEMs. (Alam et al. 2022)

The key players in this sector are: Foxconn (Taiwan), Jabil (USA), Flextronics (Singapore). (Alam et al. 2022)

2.3 MACROECONOMIC TRENDS IN SEMICONDUCTOR VALUE CHAIN

There are some macroeconomic trends that impact the value chain of semiconductors. They will be analysed below.

Slowdown of Moore's Law

Moore's Law describes the development of microelectronics. It states that the complexity of microcircuits (e.g., measured by the number of transistors per chip or per unit area) doubles periodically, with an expected period of 18-24 months. This law has greatly influenced the semiconductor industry, motivating companies to achieve a very high rate of innovation, going to increase exponentially the computing power and reducing the cost of chips. (Alam et al. 2022)

Recently, there has been a slowdown in Moore's Law. This is because for many companies have become economically unsustainable supporting these rhythms, mainly because of the higher costs of fabrication plants and the fact that semiconductor process technology becomes more complex. (Alam et al. 2022)

Software-hardware co-design is an important opportunity to develop a new level of innovation. This is because, despite the fact that over the years the development of hardware has guided the industry on the trajectory of Moore's Law, in the last period there have been only small improvements, and therefore the co-design of software-hardware can represent a new opportunity. This new opportunity requires a revolution in the way engineers work, so that new design values, tools, and stage-gate processes can be adopted, as at present hardware and software development are largely disconnected. Therefore, it is important that these two processes are interconnected, so changes in hardware immediately affect changes in software and vice versa. (Alam et al. 2022)

New emphasis on sustainability

The increasing focus on sustainability has also impacted the semiconductor industry. Companies operating in this sector are looking to increase energy efficiency and invest in sustainable production processes through new devices, materials, and renewable energy sources. (Alam et al. 2022)

However, the semiconductor industry remains a resource-intensive and carbon-emitting industry. In addition, levels of water use and chemical waste remain high, and the recycling process is costly and complex. Finally, the increased demand for chips is expected to further increment the exploitation of resources. (Alam et al. 2022)

The environmental impact has serious repercussions on the resilience of the value chain of semiconductors, which is why the companies that are part of it are adapting their strategies in response to this important issue. An example of this is the fact that many companies have stated they want to reduce water usage, power consumption, emissions, and increase the use of renewable energy. (Alam et al. 2022)

Talent shortage

Most semiconductor companies agree that there is a serious talent shortage. They are mainly computer scientists, data scientists, electrical, mechanical and chemical engineers. This negative trend exists not only in this industry, but throughout all the technology world, because STEM talents are attracted mainly by the most important software companies, which can offer very high salaries, and the promise to greatly influence technological innovation in the future. (Alam et al. 2022)

While remote work has expanded the range of talent a company can tap into, the risk of failing to hire people remains high. In fact, fewer and fewer talents decide to work in the semiconductor industry, due to lack of field awareness or uncertainty about long-term career potential. (Alam et al. 2022)

In this regard, some semiconductor companies are moving to reduce the risks of talent shortage. These moves include recruiting, retaining, and developing talent, such as investing in STEM programs, or projects designed to encourage high school students to pursue a career in STEM and attend technical universities. (Alam et al. 2022)

Onshoring manufacturing capacity

Onshoring is the practice of transferring a business, previously transferred abroad, to the country from which it was originally transferred. Onshoring allows great flexibility within organizations, and, moreover, production coordination and communication are more effective and efficient. Most semiconductor companies are investing in domestic chip production to address the various supply risks. Although this may lead to a considerable increase in costs and a delay in technological progress, they are moving in this direction. (Alam et al. 2022)

Indeed, on the public sector side, the European Union is investing to try to increase chip production by about twice, and consequently increase its market share; the United States are investing in semiconductor research, design, and manufacturing; South Korea is moving to increase R&D and investments in new plant construction; Japan is investing to reinvigorate this sector, considered very important for the country. (Alam et al. 2022)

On the private sector side, similarly many companies are investing to increase domestic capacity, through the construction of new production facilities. (Alam et al. 2022)

Explosion of AI, ML, Edge computing, 5G use cases

Given the great development of AI, ML, edge computing, and 5G technology, semiconductor companies are moving to try to take advantage of this new opportunity. 5G technology enables higher speeds and high capacity for more devices. Thanks to this, 5G technology has been able to lead to the development of AI, ML, edge computing. (Alam et al. 2022)

The fields of application of semiconductors enhanced by these new technologies can be:

- smart defence, such as swarming drones, intelligent weapons, satellites, and DARPA technologies;
- smart city, such as smart cameras to improve traffic flow, pedestrian safety, parking, and law enforcement;
- smart home, such as connected home ecosystem, smoke alarms, video surveillance, lighting, appliances;
- smart manufacturing, such as robot-assisted assembly line monitoring, predictive maintenance, production monitoring;
- smart agriculture, such as precision crop monitoring, farming drones, smart sensors on livestock, driverless tractors;

- smart retail, such as smart cart automated checkout, smart shelf inventory tracking, in-store product recommendations;
- smart mobility, such as autonomous driving, automated parking, advanced, pre-collision assist, infotainment;
- smart healthcare, such as pandemic compliance control monitoring, inventory tracking, precision medicine, remote patient monitoring. (Alam et al. 2022)

M&A activity

In the semiconductor industry, one of the past trends has been horizontal integration, as many companies have opted for acquiring others within their value chain stage. In the last period, there has been a change of direction, and companies have started to move towards vertical integration. This is to get in possession of the entire technology stack, acquiring companies that deal with a different stage from their own in the value chain. (Alam et al. 2022)

Since 2020, there has been a boom in M&A activity in the semiconductor sector, aimed especially at exploiting synergies in production capacity, product portfolio diversification, and new market entry. Below are listed the most important M&A transactions since 2020:

- Analog Devices & Maxim, in which Analog Devices acquired Maxim to further strengthen its position as a manufacturer of high-performance analog semiconductors;
- AMD & Xilinx, in which AMD acquired Xilinx to combine a highly complementary set of products, customers and markets with different IPs and world-class talent to create the industry's high-performance and adaptive computing leader;
- Intel & SK Hynix, in which SK Hynix acquired Intel's NAND division to strengthen its position in the storage solutions market;
- Renesas & Dialog, in which Renesas acquired Dialog to extend its leadership in delivering embedded solutions for the fast-growing IoT, industrial, and automotive markets;
- Marvell & Inphi, in which Marvell acquired Inphi for accelerating growth and leadership in cloud and 5G infrastructure;

- Qualcomm & Nuvia, in which Qualcomm acquired Nuvia to strengthen its position thanks to the company's technology to develop a high-performance and energy-efficient CPU. (Alam et al. 2022)

Ballooning venture capital investment

In the last period, venture capital companies have started investing in startups related to the semiconductor industry. This appears as a new trend, as venture capital companies have historically been interested in investing in software startups rather than hardware. In fact, venture capital companies that have always been focused on investing in software companies, such as Battery Ventures, Bessemer Venture Partners, and Foundation Capital, are now exploring investments in the chip industry startups. (Alam et al. 2022)

Some of the most funded startups in the semiconductor industry include:

- SambaNova Systems (USA) with focus on software, hardware, and services to run AI applications;
- Tenstorrent (Canada) with focus on AI chips and software;
- Groq (USA) with focus on high performance ML chips;
- Mythic (USA) with focus on advanced AI inference for edge devices;
- SiFive (USA) with focus on open-source semi technology & software automation;
- Ambiq Micro (USA) with focus on mixed-signal solutions for wireless electronics;
- Rockley Photonics (USA) with focus on photonics chips and custom integrated packaged products. (Alam et al. 2022)

3. THE SEMICONDUCTOR SHORTAGE: FOCUS ON AUTOMOTIVE INDUSTRY

3.1 CAUSES OF SEMICONDUCTOR SHORTAGE

Starting from the beginning of 2020, there has been the most severe global shortage of semiconductors ever seen. The COVID pandemic has certainly had a great impact, but it was not the only determining factor. The causes of this crisis can be grouped into three categories, which will be analysed below.

COVID-19 Disruptions

The COVID pandemic has caused losses in almost all industries, including the semiconductor industry. Precisely, this pandemic has led to three major destructions: demand, supply, and workforce disruptions. (Mohammad, Elomri, Kerbache 2022)

Demand disruption is given by the set of different events. First of all, the sudden increase in demand for products for work from home (WFH), such as laptops, tablets, smart home devices, due to the fact that with the various lockdowns, people were forced to work and study from home, and they had to equip themselves with the necessary tools. In addition, demand for consumer electronics has increased, to make quarantine life more comfortable. What has happened has been the opposite of what was expected, because the loss of income caused by the pandemic should have reduced consumption, as it had done in the crisis of 2008-2009. A second important factor was the closure in 2020 of many of the auto parts suppliers' factories to mitigate the risk of infection from the virus, and the cancellation of chip orders from car manufacturers to avoid the increase in inventory costs. This is because the decrease in car sales, recorded at the beginning of the year, was expected to continue for at least another one to two years. But again, what happened was the opposite. The decrease of restrictive measures and of the fear of contagion have led to a new increase in the sale of cars. In fact, in the people, who gradually returned to a normal life, the desire to travel increased but preferably by car, because plane, train, and bus would lead to close contact with other people. (Mohammad, Elomri, Kerbache 2022)

In the case of the supply disruption, this is the result of different events. First, the forced closure of chip production plants, due to lockdowns and other external shocks, caused by natural disasters or human error. In fact, the production of semiconductors is concentrated in the East Asia area, and it is characterized by a long manufacturing cycle time. Moreover, companies operating in this sector are highly specialized and indispensable in the value chain, therefore it is difficult to find a replacement for the supply. Precisely because of these reasons, the various external shocks that have occurred in this area, shown in Table 2, have led to supply disruption. (Kleinhans, Hess 2021)

Table 2: External shocks in global semiconductor supply chain

Year	County/City	Incident	Process step	Affect corp.
2020	Japan (Sakurashimo)	Fire	Chemicals	Nittobo (ABF)
2020	Taiwan (Taoyuan City)	Fire	Chemicals	Unimicron
2020	Japan (Nobeoka City)	Fire (3 days)	Fab	AKM
2020	Taiwan	One hour power outage	Fab	Micron
2021	Taiwan	Second fire	Chemicals	Unimicron
2021	Japan (Tokyo, Fukushima, Shirakawa)	Earthquake & power outage	Fab, Chemicals	Renesas, Shin-Etsu
2021	US / Texas	Winter storm, power failure	Fab	Samsung, NXP, Infineon
2021	Japan (Hitachinaka)	Fire	Fab	Renesas Naka factory
2021	Taiwan	Drought, freshwater reservoir shortage	Fab	TSMC, UMC
2021	Taiwan	Temporary power outage at Tainan Science Park plant (7 hours)	Fab	TSMC
2021	Malaysia	Lockdown measures	Back-end Fab	Infineon Technologies, NXP Semiconductors,

				STMicroelectronics, Intel, Texas Instruments, ASE, Amkor, TFME, Hua Tian, etc.
2021	Taiwan	Lockdown measures	Back-end Fab	King Yuan Electronics Co
2021	Vietnam	Lockdown measures (Saigon Hi-Tech Park)	Back-end Fab	Intel, Samsung
2021	China	Power rationing	Front-end/Back-end Fab	Suzhou Keyang Semiconductor, Pegatron, Chang Wah Technology, Eson Precision Engineering, Unimicron, etc.
2021	Germany (Dresden)	Power outage	Fab	Bosch, Infineon
2021	Japan (Hitachinaka)	Earthquake	Fab	Renesas

Source: Kleinhans, Hess 2021

Another factor of extreme importance, always tied to the supply disruption, is attributable to the problems related to the logistics. In fact, during the period of the COVID pandemic, the decrease in the number of flights and the closure of many airports caused delays in the delivery of chips. In addition, most of the aircraft's transport capacity was allocated to all the medical items needed to combat the consequences of the pandemic. In 2020, total air cargo capacity decreased by 20%. (Alam et al. 2021)

Finally, workforce disruption was caused by the sudden need to move to work from home. This required greater flexibility in the workforce of employees and employers, and the need to equip themselves with new tools for remote working. In addition, the prolonged period of remote working and social alienation negatively affected employee's morale. (Mohammad, Elomri, Kerbache 2022)

Semiconductor supply chain complexity

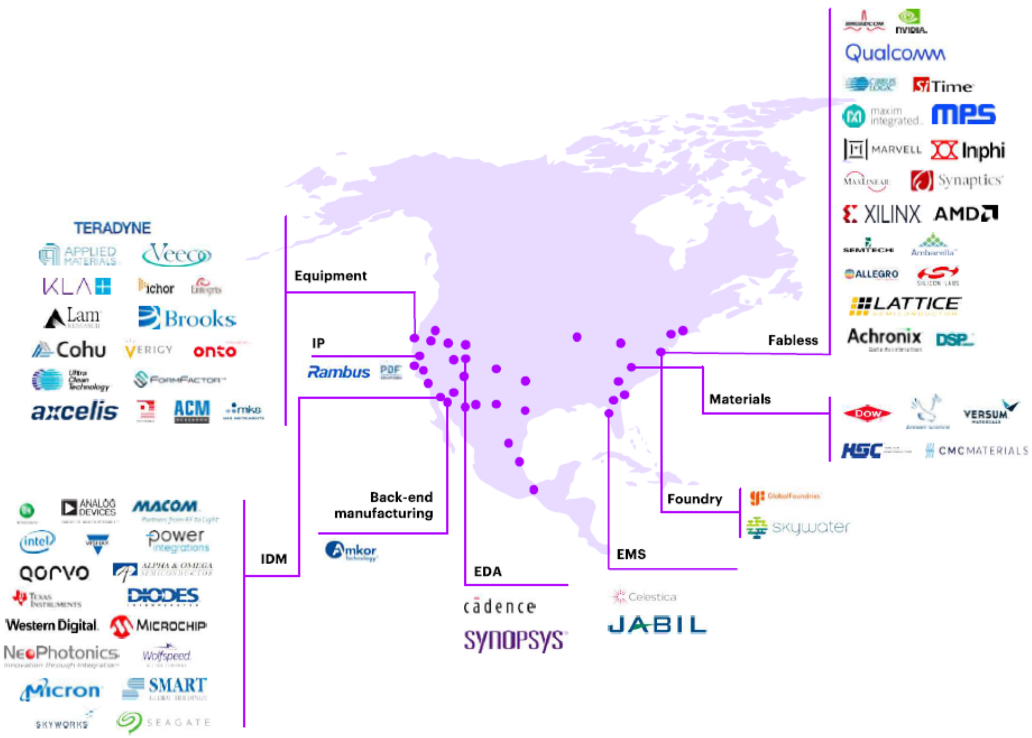
The semiconductor supply chain is extremely complex, just think that up to 1400 steps are required to produce a semiconductor, depending on whether it is a more or less advanced product. The complexity issues are related to the long fabrication cycle times, the high costs since it is a capital-intensive industry, and the fact that the production process cannot be completed in a single location but it extends over a vast geographical area. (Mohammad, Elomri, Kerbache 2022)

Starting with the fabrication cycle times, this can last up to 26 weeks. In fact, producing a wafer takes 12 weeks, up to 20 weeks for the most advanced semiconductors. Moving on to the step of back-end manufacturing, which includes assembly, testing, and packaging, this can take up to 6 weeks. Finally, it is also necessary to take into account the time that elapses between the moment when the product is completed, and the time in which it is delivered to the customer who placed the order. (Mohammad, Elomri, Kerbache 2022)

Another important factor is the characteristic of being a capital-intensive industry. In fact, the process of making a wafer can cost as much as $10 billion, especially because of the expensive equipment used (these can cost as much as $100 million each). To cope with the increase in demand for semiconductors, an attempt has been made to increase the production capacity of foundries, which is already over 80%, with peaks of 90-100% of some foundries. But further increasing production capacity is not so easy, since, given the complexity of the production process and the cost of the equipment, it is a time consuming and expensive process. Because of this, the entire expansion process can last up to 9 months. (Mohammad, Elomri, Kerbache 2022)

Finally, another factor of complexity of the supply chain, is the fact that it is localized in a vast geographic area. It is possible to distinguish three different regions. The first is North America, where of particular importance for the semiconductor industry are Silicon Valley and Austin. Silicon Valley is considered to be the birthplace of the semiconductor industry, and today is known primarily for specializing in software. The strong point of this location is the large presence of hardware and software engineering talents, thanks to the proximity to prestigious research institutes. For what concerns Austin, it is characterized by low startup costs, business-friendly regulations, and wide access to a pool of talent due to its proximity to prestigious universities. All of these factors helped make the city a semiconductor hub. Like Silicon Valley, Austin specializes in some value chain activities such as EDA, design, manufacturing, and equipment. Figure 3 shows the main companies of the region, divided into the various step of the value chain. (Alam et al. 2022)

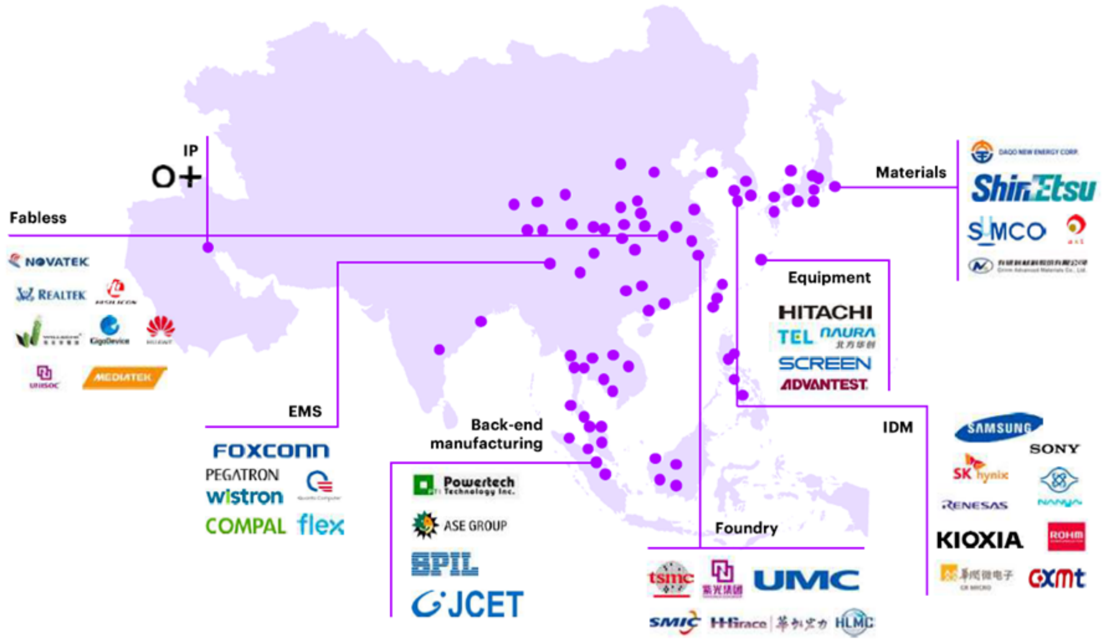
Figure 3: North America semiconductor ecosystem (Note: illustrative geographic value chain clustering; semiconductor companies across each stage of the value chain are found in more than one region; does not include all semiconductor companies in each region)



Source: Alam et al. 2022

Another particularly important region is that of APAC, which includes the countries of Asia Pacific. This region has advantages in terms of low costs, to be a favourable environment for businesses in terms of regulation, and the proximity to the largest consumer market. In fact, 75% of the global semiconductor production capacity is concentrated in this region, and 100% of the production capacity of the most advanced ones. Among the main countries in this region there are: Taiwan, China, Japan, South Korea, Singapore. Taiwan is known for being a chip manufacturing, test, and assembly powerhouse. The semiconductor industry is very important for the country, in fact the government offers strong incentives. It is also very important globally, because it is one of the two locations where the most advanced semiconductors are produced. China plays an important role in the production and assembly of semiconductors, and it has recently started investing in the design step. The Chinese government has started to invest heavily in this industry to grow globally. In addition, it can boast several advantages, such as the wide availability of natural resources, low operating costs, and proximity to the markets of end users. For what concerns Japan, its role in the industry was very important in the '70s, with a market share of 50%. Over the years the share has decreased a lot, but the country still remains a leader in the export of automotive and consumer electronics. South Korea, together with Taiwan, is the second location that is able to produce the most advanced semiconductors. In addition, the country's government is investing heavily to strengthen the domestic industry, through subsidies and tax incentives. Singapore is also significant within this industry, as it can count on a wafer production capacity of 5%. In addition, the country's government has announced that it intends to increase capacity by up to 50% by 2030. One of the country's strengths are partnerships with universities, which promote innovation in R&D and chip design. Figure 4 shows the main companies of the region, divided into the various step of the value chain. (Alam et al. 2022)

Figure 4: APAC semiconductor ecosystem (Note: illustrative geographic value chain clustering; semiconductor companies across each stage of the value chain are found in more than one region; does not include all semiconductor companies in each region)

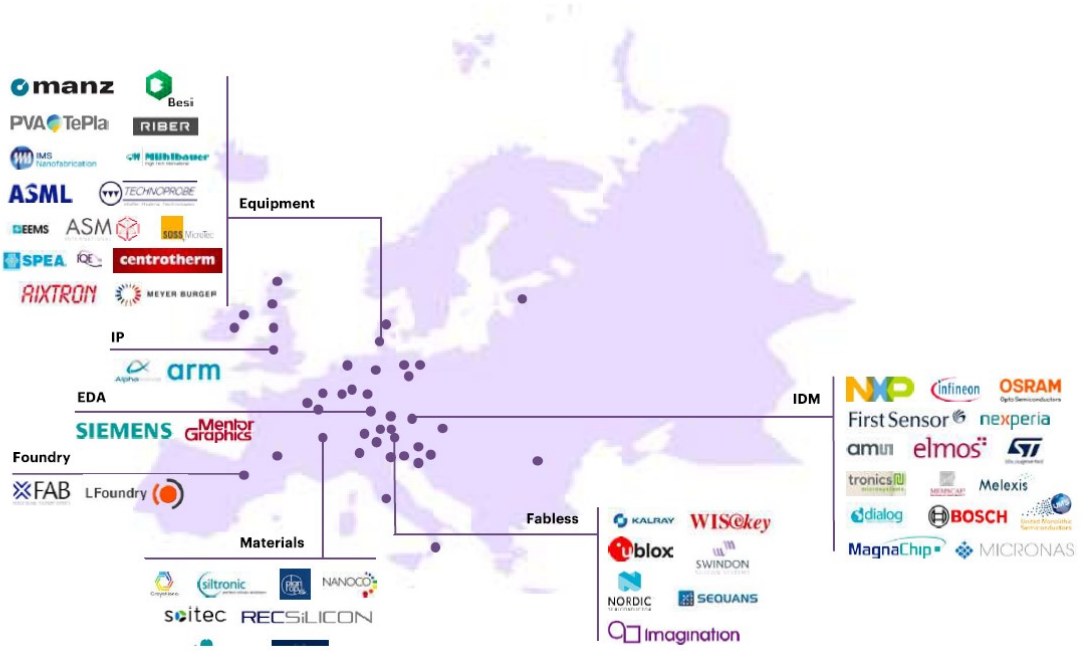


Source: Alam et al. 2022

The last major region in the semiconductor value chain is Europe. This region specializes in the production of semiconductors for the automotive and industrial segments. The advantage of this area is that production takes place close to end users, which leads to a reduction in shipping times and a strengthening of customer relationships. Figure 5 shows the main companies of the region, divided into the various step of the value chain. (Alam et al. 2022)

A company, that is part of this region, is especially crucial for the entire value chain of semiconductors. In fact, ASML is a company located in the Netherlands, and it is the only one in the world to possess the technology to build extreme ultraviolet lithography machineries, considered the future regarding wafer slicing. (Das 2023)

Figure 5: European semiconductor ecosystem (Note: illustrative geographic value chain clustering; semiconductor companies across each stage of the value chain are found in more than one region; does not include all semiconductor companies in each region)



Source: Alam et al. 2022

In summary, each of the geographic areas mentioned specializes in some steps of the semiconductor value chain. In the design and high-end manufacturing steps are specialized mainly the regions of North America and Europe; raw materials are supplied by Japan, United States and some European states; in the development of highly advanced equipment excel United States, Japan, and Europe; in manufacturing assembling, testing, and packaging stand out China, Taiwan, and other Asian countries. (Mohammad, Elomri, Kerbache 2022)

The advantages of this type of specialization are many, such as:

- opportunities to tap into existing suppliers, local talent, and well-developed infrastructure;
- exploit the interconnection between industry and universities;

- meet the needs of domestic consumers, due to the proximity of the market. (Alam et al. 2022)

Nevertheless, a value chain structured in this way is vulnerable for several reasons, such as:

- vulnerability to natural disasters, and instability and geopolitical tensions, which can cause large scale disruptions because of single points of failure;
- cross-border transport can cause logistical problems, costs, and lag time;
- skill shortages in areas not focused in the semiconductor value chain;
- partnerships with universities and research institutions require time and resources to be developed and to produce successful results. (Alam et al. 2022)

Finally, operating in different geographical areas also poses problems with regulation, as each country has its own rules. An example of this are environmental regulation and IP protection. In the case of environmental regulation, this is a regulation that set limits on hazardous waste. The European Union has issued the Waste Electrical and Electronic Equipment (WEEE), which sets out guidelines to minimize waste in landfills, and the Restriction of Hazardous Substances (RoHS), which limits the use of lead and mercury in the production of a certain type of material, including those for semiconductor production. Similarly, the United States, China, Japan, and South Korea have enacted regulations to reduce the use of these hazardous materials. In particular, US legislation regulates the use of fluorinated gases or heat transfer fluids in semiconductor companies. In addition, it is important to note that when a semiconductor foundry wants to expand or wants to open a new plant, it must obtain specific land, zoning, and building permits from local authorities, which vary according to the country in which they want to be located. (Alam et al. 2022)

With regard to IP protection, various regulations have been issued over the years. The most important examples are the following: America's Semiconductor Chip Protection Act, that aims to protect chip topography and design layout IP; the EU's Legal Protection of Topographies of Semiconductor Products, issued with the purpose of protecting IC design; the Trade-Related Aspects of Intellectual Property (TRIPS) agreement, issued by the World Trade Organization, was the first to define rules and procedures of application of IP. (Alam et al. 2022)

Finally, depending on the country also vary the tax laws and import controls. (Mohammad, Elomri, Kerbache 2022)

Geopolitical Issues

In recent decades, geopolitical tensions have grown globally. Of particular importance for the semiconductor industry are the tensions between Japan and South Korea, and the United States and China. (Mohammad, Elomri, Kerbache 2022)

Although the tensions between Japan and South Korea have not been very damaging to the semiconductor industry, it is important to point out that these could become disruptive to the supply chain in the future. Starting from July 2019, following South Korean rulings against Japanese companies, Japan decided to impose restrictions on exports to South Korea. South Korea's main concern was that these exports would also include the chemicals needed for semiconductor production, such as hydrogen fluoride, fluorinated polyimide, and photoresists. Japan is extremely important for the export of these three chemicals, in fact it counts for about 70% of the global supply of hydrogen fluoride, for 90% of the supply of fluorinated polyimide, and in equal measure also for the supply of photoresists. Although South Korea has a value of only $400 million per year for the import of these chemicals from Japan, the country has a value of $80 billion per year for the export of semiconductors. And the value of these exports also depends on being able to find the substances needed to make semiconductors. During 2020, these tensions have been diminishing, thanks to the fact that Japan has readmitted exports of these precious substances to South Korea. Although this improvement has occurred, the situation remains delicate and the risk for the semiconductor supply chain remains, as South Korea is one of the leading countries in terms of chip export. (Varas et al. 2021)

One of the causes that has led to the evolution of the semiconductor crisis is the trade war between the United States and China started in 2018. The goal for the US was to make the production of semiconductors in China difficult, and to prevent it becoming a leader in the production of more advanced ones. Initially, the United States hit imports from China, with a series of tariffs aimed at targeting raw materials for chip production, such as silicon and reactor tubes, and holders designed for semiconductor wafer production. This was one of the main factors that caused the wafer shortage in 2019. Moreover, in 2020 the United

States imposed restrictions on the Semiconductor Manufacturing International Corporation (SMIC), the largest semiconductor firm in China. These restrictions made it difficult for SMIC to sell to other firms with American ties. The situation forced companies all around the world to use other manufacturing plants like Taiwan Semiconductor Manufacturing Company Limited (TSMC) and Samsung. But the problem was that companies already producing at maximum capacity. (Fusion Worldwide 2021)

These measures escalated when the United States began to impose export controls, between 2019 and 2020, to restrict Chinese companies' access to semiconductors containing US technology. These restrictions were justified by the United States in order to protect national security. (Varas et al. 2021)

One of the main Chinese companies affected by these restrictions was Huawei, which was banned from being partner with US companies. In particular, the United States were important to Huawei for EDA companies, which in fact are mainly based in America. However, these sanctions have backfired not only against Huawei, with a drop in global smartphone shipments, but also against the United States, whose consumers have had limited access to smartphones. Shocks caused by geopolitical tensions between two or more countries have effects that can be devastating not only at the point where they occur, but also in large sections of the supply chain, up to the end users. (Alam et al. 2022)

3.2 IMPACT OF SEMICONDUCTOR SHORTAGE ON VARIOUS INDUSTRIES

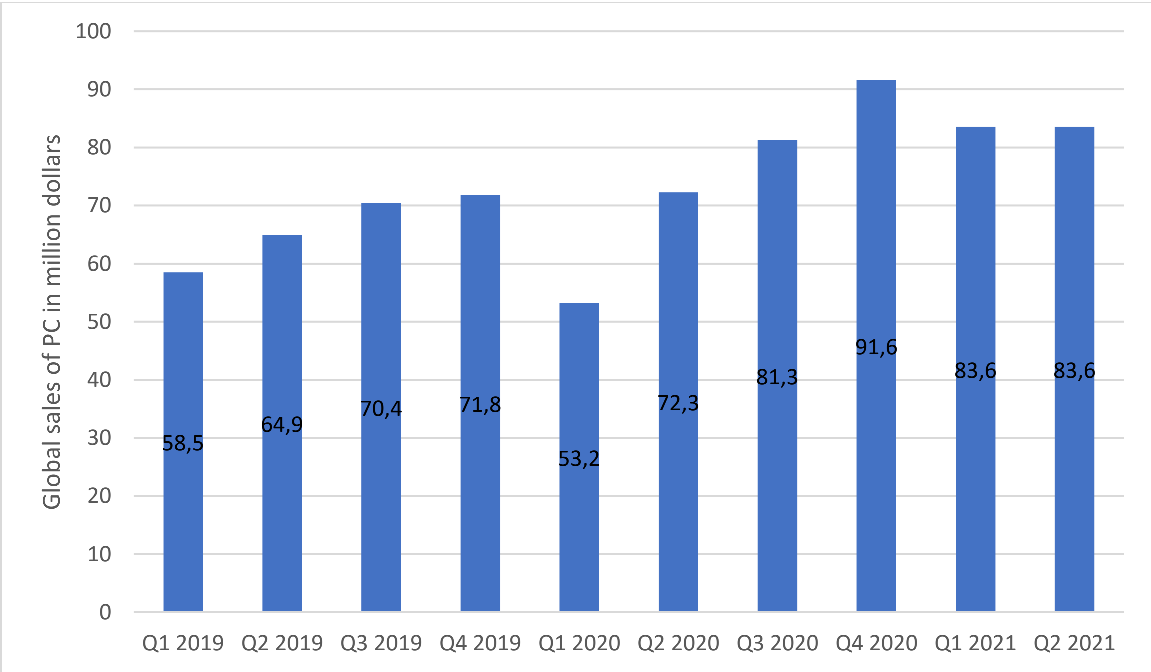
The semiconductor crisis affected 169 industries, particularly the automotive industry. Below are listed the industries that have experienced the greatest repercussions, in addition to that of the automotive. (Mohammad, Elomri, Kerbache 2022)

Computer sector

As described above in this chapter, in the paragraph dedicated to the causes of the semiconductor shortage, demand for laptops and tablets has increased exponentially since 2020. This is because of the lockdowns caused by the pandemic, and the consequent fact that people, working and studying from home, had to equip themselves with the necessary tools. In fact, as shown in Chart 6, it has been recorded an increase of the global

PC shipment in 2020. Only in the first quarter of the year can be observed a decrease, due to the initial shock of the COVID pandemic. (Mohammad, Elomri, Kerbache 2022)

Chart 6: Global PC sales from 2019 to 2021



Source: Alam et al. 2022

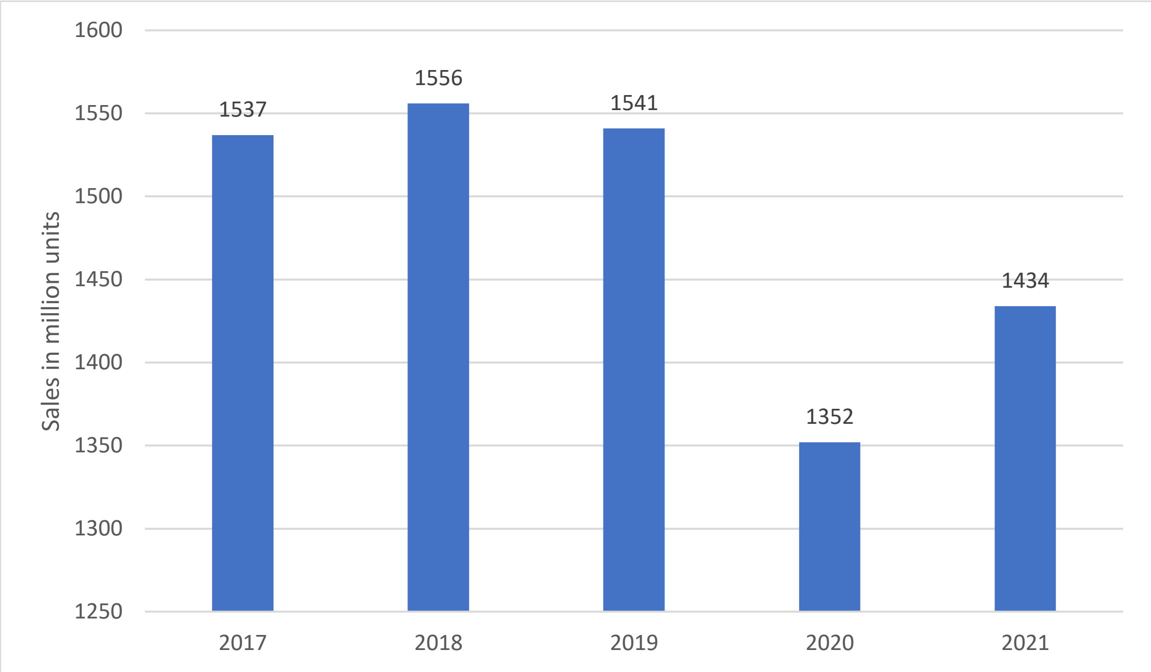
The lack of semiconductors has impacted this industry causing an increase in delivery times for some models up to 120 days, and an increase in the final price of the product, which sellers have shifted on consumers. (Mohammad, Elomri, Kerbache 2022)

For example, HP has been one of those companies forced to raise the prices of its products. In fact, as stated by the same company the mix of component shortage and logistic issue has contributed to this fact. Acer also stated that it would talk to suppliers daily to find a solution to the problem. Even Apple, known for its procurement power, has had delays in the delivery of MacBooks and iPads, due to the shortage. (Tamarov 2021)

Communication sector

The communication industry has also been hit hard by the lack of semiconductors, especially in the production of smartphones. In fact, in 2020 there was a decrease in smartphone sales of 12.5%, as shown in Chart 7. Many companies in this industry received only 80% of the total semiconductors they had ordered, decreasing smartphone production and increasing the price of this product. About 90% of all industry has been affected by this crisis. (Mohammad, Elomri, Kerbache 2022)

Chart 7: Number of smartphones sold to end users worldwide from 2017 to 2021



Source: Statista 2022c

The effects of this crisis have been visible in many of the most well-known companies in the sector. For example, Samsung was affected in one of its most famous products, and it was forced to cancel the Galaxy Note series in 2021. Other companies such as Oppo and Xiaomi have also been affected, resulting in higher prices for their products. Only Apple seems to maintain a good position, proving to be more resilient than other manufacturers in the field of smartphones. (Mohammad, Elomri, Kerbache 2022)

Consumer electronics sector

The semiconductor crisis has also affected the consumer electronics industry, especially with regard to some types of products, such as TVs, cameras, printers, gaming consoles. (Mohammad, Elomri, Kerbache 2022)

The demand for TVs has grown a lot during the COVID pandemic, because of the various lockdowns people forced at home have started wanting to improve their devices, in order to benefit from greater comfort. But the semiconductor crisis has raised the final price of TVs by 30%. In particular, this is linked to the fact that older types of semiconductors are needed to produce devices that contain integrated circuits linked to the display, and this type of less advanced semiconductors is created in foundries that have mainly failed to meet demand. (Mohammad, Elomri, Kerbache 2022)

The camera segment was also affected. In fact, among the most famous companies operating in this sector, Sony had to suspend in 2021 the production of the new line ZV-E10 mirrorless vlogging camera, just because of the lack of semiconductors. In addition, Fujifilm, Nikon, and Canon were also attacked by the crisis. For example, Canon's EOS R3 Mirrorless Camera line has been delayed in shipping. (Mohammad, Elomri, Kerbache 2022)

For what concerns the printer manufacturers, one of the most famous examples was that of Canon that had to teach its customers how to bypass its DRM controls to allow the use of printers. The reason for this is that the lack of semiconductors has made it impossible for Canon to continue producing ink cartridges with integrated DRM. DRM is a protocol that forces consumers to buy cartridges from the same company from which the printer comes, and it is a strategy used by many manufacturers to charge a higher price than what consumers would pay by turning to third parties for the purchase of cartridges. (Mohammad, Elomri, Kerbache 2022)

Finally, the gaming console segment was not spared either. The lack of semiconductors has made it difficult to find some of the most popular consoles, including the PS5 by Sony, the Nintendo Switch by Nintendo, the Xbox Series X by Microsoft. This is because the gaming industry is heavily dependent on two main types of chips: CPUs and GPUs. CPUs are needed to make sure that all instructions provided by a program are executed, while GPUs are indispensable to allow viewing of images during the game. (Wafer World 2021)

Industrial sector

Within this industry, it is possible to distinguish two segments that have been most affected by the semiconductor crisis.

First of all, the healthcare segment, because many medical equipment requiring the use of semiconductors. The great importance of these equipment was demonstrated mainly in 2020, in fact many of them were essential and not replaceable to combat the COVID pandemic in hospitals. For example, medical ventilators, which are controlled by semiconductors, have been vital to treat patients with severe respiratory problems caused by the virus. And just at the time when the virus has infected most people, medical ventilator manufacturers said they had a total of more than 9 million components of unmet demand. (Mohammad, Elomri, Kerbache 2022)

Another very affected segment turned out to be the Internet of Things (IoT). In fact, about 80% of the world's manufacturers have said they have encountered difficulties in the development of digital products, many of which work thanks to semiconductors. (Mohammad Elomri Kerbache, 2022)

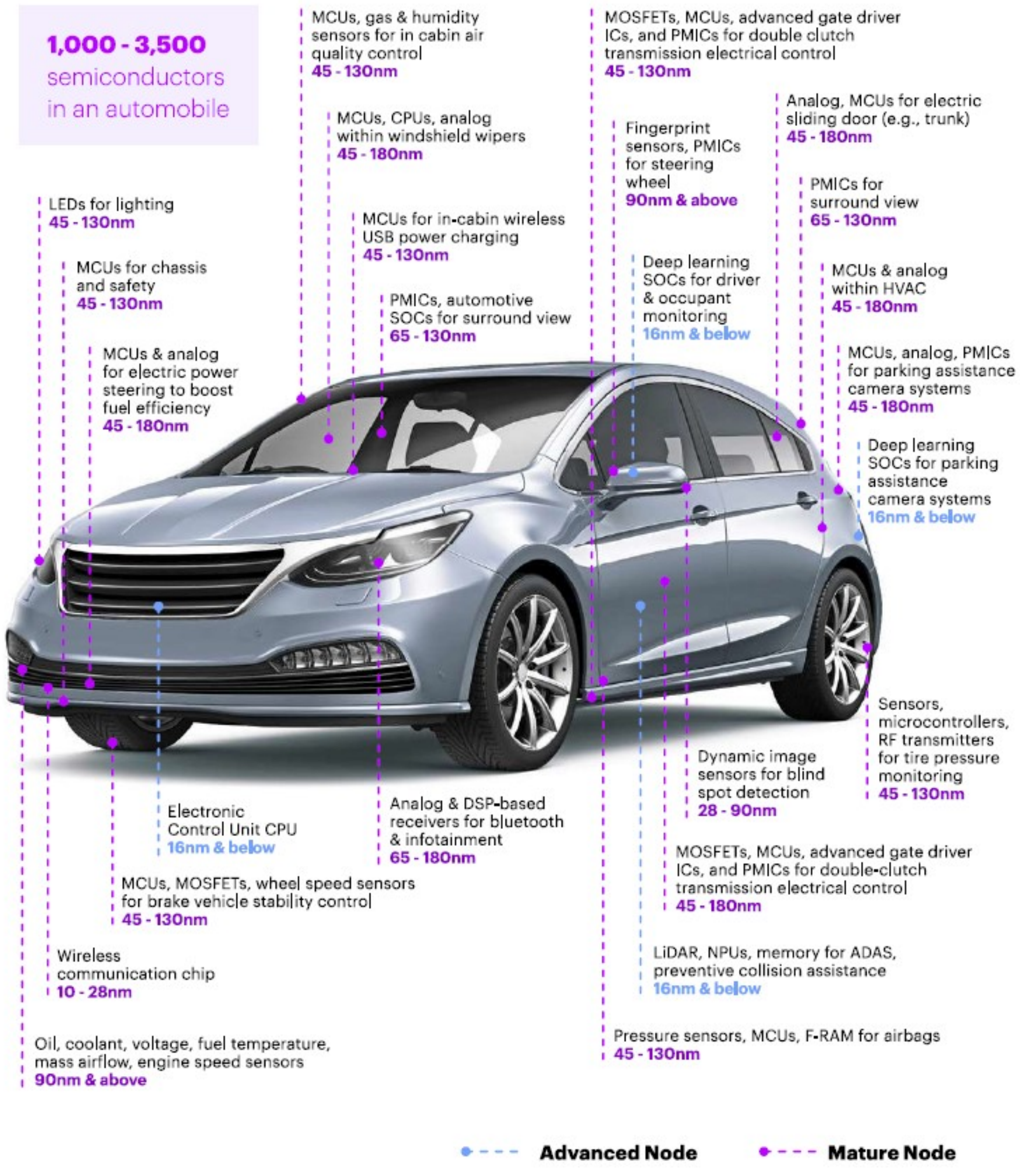
3.3 IMPACT OF SEMICONDUCTOR SHORTAGE ON AUTOMOTIVE INDUSTRY

The industry most affected by the semiconductor crisis was certainly the automotive sector. Before analysing the impacts on this industry, it is important to understand the importance of semiconductors in the production of vehicles.

In fact, as shown in Figure 6, for the construction of a car are necessary from 1000 to 3500 semiconductors, indispensable to control any function, starting for example from the emissions system or driver assistance systems, making them essential parts of the production. According to estimates, on average a car requires 1400 to 1500 semiconductors, reaching over 3000 for the most technologically advanced cars. (Straughan 2023)

In addition, the role of semiconductors will be increasingly important as the automotive industry continues to evolve towards electrification and autonomous driving. "For example, electric vehicles require sophisticated power electronics for efficient battery management and engine control. Autonomous vehicles also rely heavily on advanced sensors and processing capabilities for perception and decision making". (Drex 2023)

Figure 6: Semiconductors usage in a car



Source: Alam et al. 2022

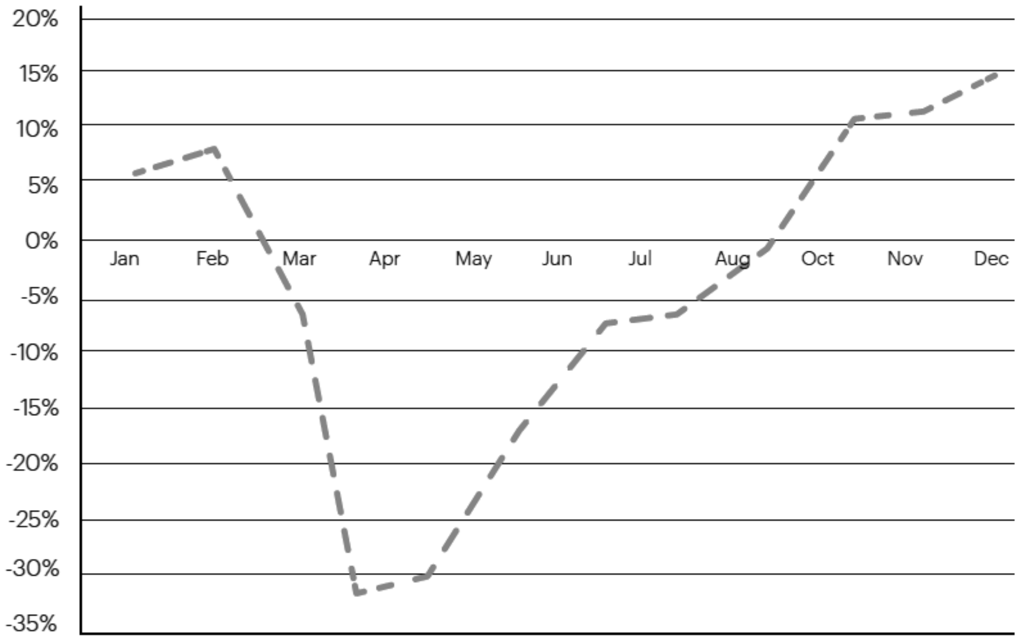
Semiconductors in cars are used for several purposes, among the main ones there are:

- infotainment systems: "semiconductor chips process data that feeds infotainment systems and manages their various functions. These systems provide drivers and passengers with entertainment and information through audio, video and other multimedia capabilities"; (Drex 2023)

- power steering: "in power steering systems, semiconductor chips help control the flow of hydraulic fluid that provides driver assistance when the steering wheel turns"; (Drex 2023)
- braking systems: "in braking systems, semiconductor chips help manage the distribution of braking force between wheels to ensure optimal stopping performance"; (Drex 2023)
- electrification of the vehicle: "semiconductors have made it possible to replace manual systems with electrical ones. Electrification of key systems offers benefits such as increased vehicle efficiency, reduced carbon emissions and reduced dependence on oil"; (Straughan 2023)
- safety and driver assistance: "the growing need for improved safety and driver assistance in automobiles has provided a niche for semiconductors. Intelligent functions such as backup cameras, blind spot detection, adaptive cruise control, lane change assistance, airbag installation and emergency braking systems are all made possible through the integration of semiconductor technologies"; (Straughan 2023)
- connectivity: "cars increasingly incorporate technologies that improve their connectivity. New vehicles on the market include increasingly sophisticated telematics (long-distance data transmission) and infotainment capabilities that provide drivers with information on factors such as road closure, collision prevention and even free parking at the destination. The onboard computers that handle this information must process millions of lines of code every second. Semiconductors allow cars to stay connected in real time". (Straughan 2023)

In addition to what was described above in the section of the causes of semiconductor shortage, the lack of semiconductors in the automotive industry has been particularly severe due to the just in time method. Just in time has characterized the automotive industry in recent history. This is a method which is used to indicate a production system perfectly oriented to the demand and the volumes required by the market. The idea is to minimize waste resulting from the accumulation of stocks of materials, semi-finished products, and finished products, also avoiding the costs resulting from the need to store large quantities of materials or finished goods. In this way, automotive manufacturers did not have a surplus when the semiconductor shortage began, and found themselves running out of those they had available. In fact, going to analyse the demand for vehicles, it is possible to see, as shown in Chart 8, that this dropped drastically in the spring of 2020, when, because of the various lockdowns, people were forced to stay at home. In addition, the forecasts saw the demand for vehicles falling even for the following months, so the automakers adjusted, reducing their demand for semiconductors. But contrary to expectations, demand started to grow very rapidly within a few months, and imperfect inventory planning caused a severe semiconductor shortage and production disruption. (Alam et al. 2021)

Chart 8: Monthly sales growth percentage change in automotive industry in 2020



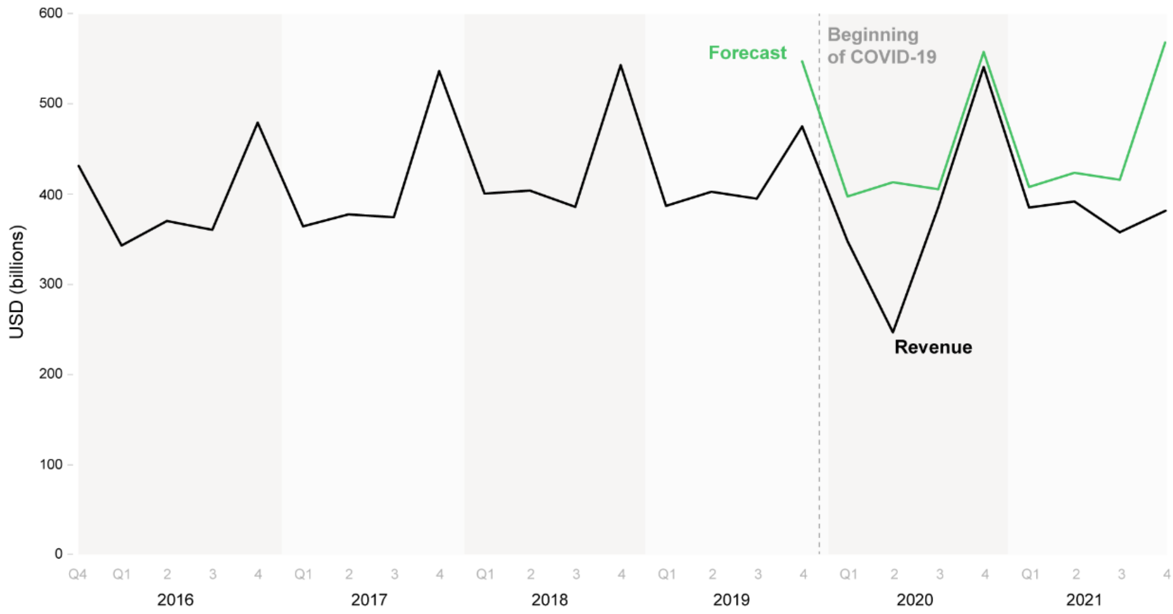
Source: Alam et al. 2021

To worsen this situation, always during the various lockdowns, the demand for the consumer electronics industry has increased, since people working and studing from home had to equip themselves with the necessary tools to do so. The production capacity of semiconductor foundries was mostly designed to meet the demand of the consumer electronics industry. This is explained mainly by a profit factor, as the semiconductors used in the two industries are not equal. The market share by application for consumer electronics and the communication industry jointly reaches almost 50% of the market, while the automotive industry only 10%. It therefore becomes more convenient for semiconductor manufacturers to concentrate their production capacity to meet the demands of the larger market in terms of sales. Moreover, the semiconductors used in the automotive industry are older than the more advanced ones in consumer electronics. As a result, it is not convenient for chip manufacturers to invest in old technology. (Busvine, Steitz 2021)

The main impacts on the automotive industry were:

- loss of revenue: as reported in Chart 9, during Q2 of 2020 car manufacturers suffered a loss of about $166 billion in sales, caused by lockdowns during the COVID pandemic and the consequent drop in demand for vehicles. In 2021, as government restrictions eased, demand recovered, but the lack of semiconductors prevented automakers from meeting demand. In fact, there was a loss of $300 billion in sales, in which Q4 of the year proved to be the worst in decades, with a loss of $186 billion in sales. In addition, previous estimates reported losses of $210 billion in sales in 2021, but the result was much worse than expected. (Avnet Silica 2022)

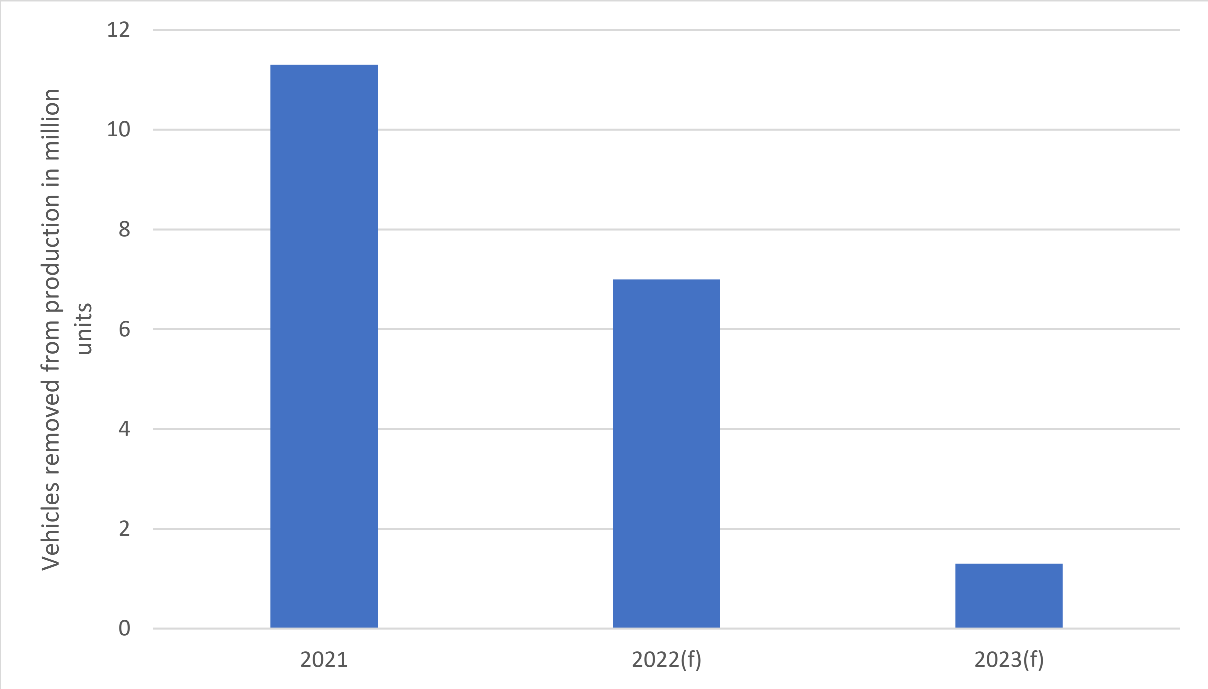
Chart 9: Combined revenue of the world's top automotive manufacturers



Source: Avnet Silica 2022

- cut in production: the lack of semiconductors has caused a global cut in production. In fact, from 2021 to 2023 is estimated a cut in the production of about 19.6 million vehicles. As shown in Chart 10, it is possible to see in 2021 a cut in production of about 11.3 million vehicles, and subsequently an estimated 7 million vehicles in 2022, and 1.3 million in 2023, despite a gradual return to normal conditions. (Straughan 2023)

Chart 10: Global automaker production cuts



Source: Statista 2022d

- price increase: because of the semiconductor crisis, car prices have risen. On average a new car is sold at a price of $48,763, while before the crisis the average price was $37,876. Even as for the used car market the situation does not change, in fact on average a car is sold for $ 26,510. The reasons behind this price increase are varied, although all of them are due to the semiconductor shortage. Firstly, as indicated in the previous point, the cutback in vehicle production has increased prices, as lower supply results in higher prices. Another reason is that car manufacturers give priority to the production of the most profitable vehicles, at the expense of the cheap ones, because it is impossible to produce the normal number of vehicles. Linked to this, it was recorded from 2017 to 2022 that cars considered cheap (under $25,000) had a 78% drop in demand, going from 13% of sales on total new vehicles, up to 4%. While, by contrast, cars above $60,000 have seen an increase from 8% to 25% of sales on total new vehicles. And because more expensive vehicles are more profitable for car manufacturers, they are focused on producing this type of vehicle. Finally, with regard to the second-hand market, this has seen an increase in prices since the lack of new cars on the market and the long lead times, that can even reach 10-12 months, led consumers to evaluate more the purchase of used cars. In addition, those few cars produced in 2021, are mostly non-economic cars, which currently have become used cars, also bringing this market to a high-end products expansion. (Domonoske 2023)

3.4 RESPONSE OF AUTOMOTIVE INDUSTRY TO SEMICONDUCTOR SHORTAGE

In response to this crisis, many automakers have decided to form strategic alliances directly with semiconductor manufacturers, to secure the amount of chips needed to meet demand for cars. In the past, automakers worked through suppliers to procure chips, while now, to secure the future supply of chips, many companies are starting to establish their own relationships. (Lee 2023)

There are several examples of strategic alliances born in this regard, some of them are listed below.

In early 2023, General Motors announced a strategic partnership with GlobalFoundries. This alliance aims to create an exclusive supply line of semiconductor products directly in the United States, and to drastically reduce the risk of a shortage of this precious component. The supply will cover that lack of semiconductors that has had a serious impact on General Motors, just think of the decrease in revenue of 10.75% in 2020. Doug Parks, executive vice president of global product development, purchasing and supply chain at General Motors said: "the supply agreement with GlobalFoundries will help establish a strong and resilient critical technology offering in the United States, that will help General Motors meet this demand while providing new technologies and functionality to our customers". (Lee 2023)

In 2021, Stellantis announced a strategic alliance with Foxconn, a leading global technology company with a lot of experience in semiconductor manufacturing. The collaboration aims to create stability in the company's semiconductor supply chain, and to create a new family of semiconductors specifically designed to fit Stellantis vehicles. Carlos Tavares, Stellantis CEO said: "with Foxconn, we aim to create four new families of chips that will cover over 80% of our semiconductor needs, helping to significantly modernize our components, reduce complexity, and simplify the supply chain. This will also boost our ability to innovate faster and build products and services at a rapid pace". (Stellantis 2021)

In 2022, Volkswagen announced a strategic alliance with STMicroelectronics, with the purpose of co-developing semiconductors. Cariad, Volkswagen's software division, will jointly develop with STMicroelectronics perfectly tailored hardware for connectivity, energy management, and over-the-air updates making vehicles fully software-defined, safe and future-proof. All the solutions that will be born from this collaboration will be implemented on the new generation of vehicles of the Volkswagen Group, with the objective to avoid that they can lack chips or vital components, and to ensure that the supply of all the chips for the Group's cars is guaranteed years in advance. Cariad CEO, Dirk Hilgenberg, said: "with the co-development of the System-on-Chip (SoC) with STMicroelectronics ahead of us, we are consistently pursuing our semiconductor strategy. The SoC we are designing will be optimally matched to our software, without compromise. In this way, we can offer our Group's customers the best performance for their cars. The use of a single, optimized architecture in all Volkswagen electronic control units will give us an enormous boost for the efficient development of our software platform". (STMicroelectronics 2022)

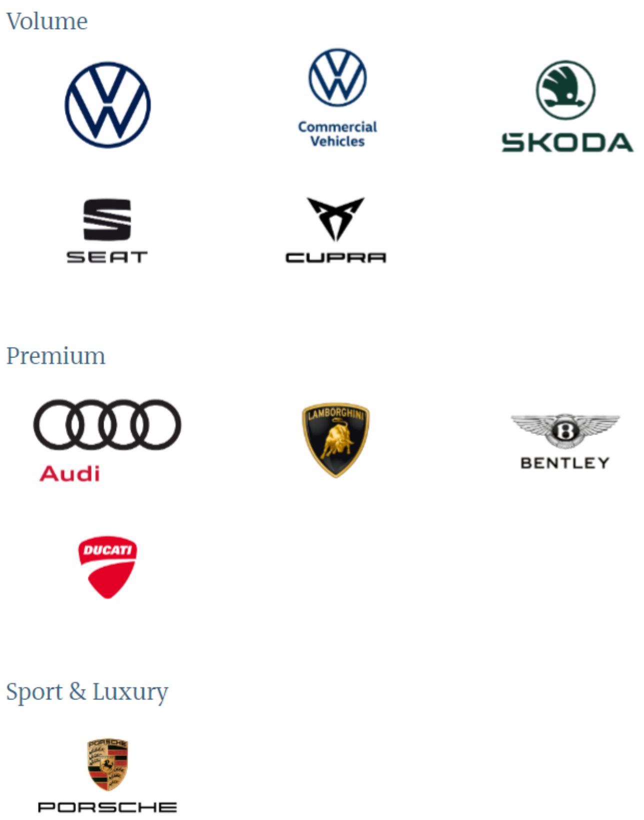
In 2021, Ford created a strategic alliance with GlobalFoundries, with the aim of increasing the supply of semiconductors in the short and long term. The collaboration will create a secure supply line for Ford's current vehicles, and it will form a joint research and development group to meet the growing demand for feature-rich chips for the future. Jim Farley, Ford president and CEO, said: "it's critical that we create new ways of working with suppliers to give Ford, and America, greater independence in delivering the technologies and features our customers will most value in the future. This agreement is just the beginning, and a key part of our plan to vertically integrate key technologies and capabilities that will differentiate Ford far into the future". (Ford 2021)

4. STRATEGIC ALLIANCES IN PRACTICE: THE VOLKSWAGEN GROUP CASE

4.1 SEMICONDUCTOR SHORTAGE IMPACT ON VOLKSWAGEN GROUP

The Volkswagen Group is a German multinational, operating mainly in the automotive sector. In fact, within this sector there are ten different brands, mostly manufacturers of cars, but there are also motorcycle and other vehicles manufacturers. The various brands are divided into three groups: volume, premium, and sport. Each of the brands has its own strategy, and it operates independently for the success of the Group. In addition to the main business, there are also brands that offer supporting services to the Group, in the field of technology, digitalisation, and mobility. (Volkswagen Group 2023)

Figure 7: Brands in the automotive business of Volkswagen Group



Source: Volkswagen 2023

Figure 8: Brands in other businesses outside automotive of Volkswagen Group

TRATON

The TRATON GROUP aims to become a global champion of the commercial vehicle industry.

CARIAD

CARIAD is an independent automotive software company in the Volkswagen Group.

VOLKSWAGEN AKTIENGESELLSCHAFT GROUP TECHNOLOGY

Group Technology is made up of the four divisions Battery, Charging & Energy, Components and Platform Business.

VOLKSWAGEN FINANCIAL SERVICES THE KEY TO MOBILITY

Volkswagen Financial Services comprises a diverse product portfolio.

MOIA

MOIA provides pioneering on-demand mobility for people in cities.

VOLKSWAGEN GROUP FLEET INTERNATIONAL

Wholesale business in the Volkswagen Group is co-ordinated by Volkswagen Group Fleet International.

Source: Volkswagen 2023

Semiconductor shortage impact on production

The impact of the lack of semiconductors on vehicle production for the Volkswagen Group was evident.

Starting from the year 2020, the German Group has recorded a sale of 9.3 million vehicles, with a decrease of 15.2% compared to the previous year. In Europe, sales have fallen by 20.5%, with 3.6 million vehicles sold. More precisely, in Western Europe the recorded decrease was of 21.6%, with 2.9 million vehicles delivered. The situation is not even better in Central and Eastern Europe with a decrease, albeit less, settles to 15.6%, with 677,000 vehicles sold. In North America, the drop in sales was 17.4% over the previous year, with 785,800 vehicles delivered. In the United States the decrease turned out to be lower, with a -12.1% and 574,800 vehicles sold. Also, in South America the increase has been negative, with a -19.5% and 489,700 vehicles delivered. Brazil, the main market of the region, has recorded the same decrease, with sales of 377,600 units. Finally, for what concerns the Asia-Pacific region, it shows a decrease of 9.1%, less severe than that of the other regions, with 4.1 million vehicles sold. China shows the same decline in growth of the region, and 3.8 million vehicles sold. (Volkswagen Group Italia 2021)

In 2021, Volkswagen Group was able to deliver about 8.9 million vehicles, with a decrease of 4.5% over the previous year, despite the steady growth of the electric vehicle segment. Also in this year, the loss is largely due to the lack of semiconductors and the COVID pandemic, but the good results obtained in America have allowed to mitigate the situation. A total of 3.5 million vehicles were delivered in Europe, down by 2.7% compared to the previous year. In particular, Western Europe recorded sales for 2.8 million vehicles, similar to the precedent year, while Central and Eastern Europe sales for 658,300 vehicles, with a decrease of 2.8%. Positive results were recorded in North America, given by an increase in sales of 15.6% with 908,400 vehicles sold. In particular, the United States showed a 16.9% increase with 671,800 vehicles sold. South America's result should be underlined, with an increase of 5.1% and 514,600 vehicles sold. Finally, the Asia-Pacific region showed the worst result, with a decrease of 12.4% compared to 2020, and 3.6 million vehicles delivered. The worst turned out to be China's market, with a drop of 14.1% and 3.3 million vehicles delivered. (Vendrame 2022)

In 2022, the German Group recorded global vehicle sales of about 8.3 million units, down by 7% compared to the previous year, although electric vehicles are growing. The reasons for this situation are always linked to the crisis of semiconductor supply, and to production stops. Although in the second half of 2022 there was a growth in sales compared to the same period of the previous year, this could not compensate for the -22% recorded in the first half, always in comparison with the same period of the precedent year. In particular, with regard to Europe, the total deliveries have marked a decrease of 10.4%, with the delivery of 3.2 million vehicles. In Western Europe the decrease was less significant, with a decline of 5.2% compared to the previous year. While in Central and Eastern Europe there has been a significant contraction of 32.9%, also due to the war in Ukraine. A total of 842,600 vehicles were delivered in North America, with a decrease of 7.2%. Going more specifically, the United States recorded sales for 631,100 units, with a decrease of 6.1%. In South America the vehicles sold were 473,700, with a decrease of 8%, and particularly relevant in a negative sense was Brazil, with a decrease of 10.4%. Finally, the last relevant region is that of Asia-Pacific, with a lower decrease than the others, recording a decline of 2.7%, with a total of vehicles delivered equals to 3.5 million. In this context, China, which is one of the main markets for the Group, closed the year with a 3.6% decrease in sales, with 3.2 million vehicles delivered. (Vendrame 2023)

However, at the level of the various brands in 2022, those who have managed better the shortage of semiconductor were the premium ones. In fact, Porsche records deliveries of +3% with 309,900 vehicles, Lamborghini of +10% with 9,233 vehicles, Bentley of +4% with 15,174 vehicles. Among these, only Audi shows a -4% with 1.6 million vehicles sold. For what concerns the other brands of the Group, it is important to highlight the remarkable result of Cupra, with a +93% and 152,900 vehicles sold. While, Volkswagen and Seat are both down, respectively by 7% and 41%. (Riparte l'Italia 2023)

Semiconductor shortage impact on vehicle characteristics

The causes of the semiconductor crisis have spilled over not only to the lower production, but also to the characteristics of cars. Below are listed some examples.

Volkswagen has decided to eliminate some features from its low and medium-end models, while keeping them in the high-end and top-of-the-range of the same models. This has affected models like Atlas, Tiguan, Golf GTI, Golf R, which, for example, may not be equipped with blind-spot monitors with rear cross-traffic alert, or a hands-free liftgate. (Rogers 2022a)

Audi was also forced to adapt in a similar way as described for Volkswagen. However, in this case, the car manufacturer opted for the removal of features from some lines of models, without distinction between low and high-end of the same, calling them models with "semiconductor shortage package". Some of the most affected models were A3, A4, A5, A6, A7, Q3, Q5, Q7, Q8, which may lack blind-spot monitors with rear cross-traffic alert, rear collision detection system, adaptive cruise control, lane assist, or wireless charging pad. (Rogers 2022b)

Skoda was forced to eliminate some safety technology and luxury features from Kodiaq family SUVs models, such as 360-degree camera, side assist, rear cross-traffic alert, electric child safety lock on the rear doors, and the 12-speaker Canton premium audio system. The company has even had to suspend the production of some variants of Scala and Kamiq small SUVs for some time. (Dowling 2022)

Another example concerns Porsche, which for many months has not been able to offer to the buyers of famous Macan SUV the option of the 18-way adjustable seat, which allows front occupants to adjust things like height and positions, as well as squab inclination and depth, lumbar support level and the side bolsters. In addition, on some models of the automaker, it was not possible to enter the option of electric steering column adjustment, which was then added later, once the components were back in stock. (Blanco 2021a)

Semiconductor shortage impact on production plants

The semiconductor crisis has also led to the temporary closure or reduction of the production capacity of some production plants. Below are listed some examples.

Seat has stopped production at the Martorell plant in Spain, where the Ibiza, Leon, and Cupra Formentor models are produced. The Tarraco model line, produced at the Wolfsburg plant in Germany, was also affected by the reduction in production at the Volkswagen Group's most important plant. In fact, the German Group was forced to cut the production of its main plant, which required a rearrange production schedules. (Popa 2022)

In 2021, production of the Bratislava plant in Slovakia, of Volkswagen Group, stopped for more than a week. The models affected by the closure were especially SUVs, such as Volkswagen Tuareg, Porsche Cayenne, Audi Q7 and Q8. (Blanco 2021b)

Also recently, in early 2023, Skoda announced the cut of production for a few days of some of its models. These include Octavia, Enyaq, Fabia, Scala, and Kamiq. (Popa 2023)

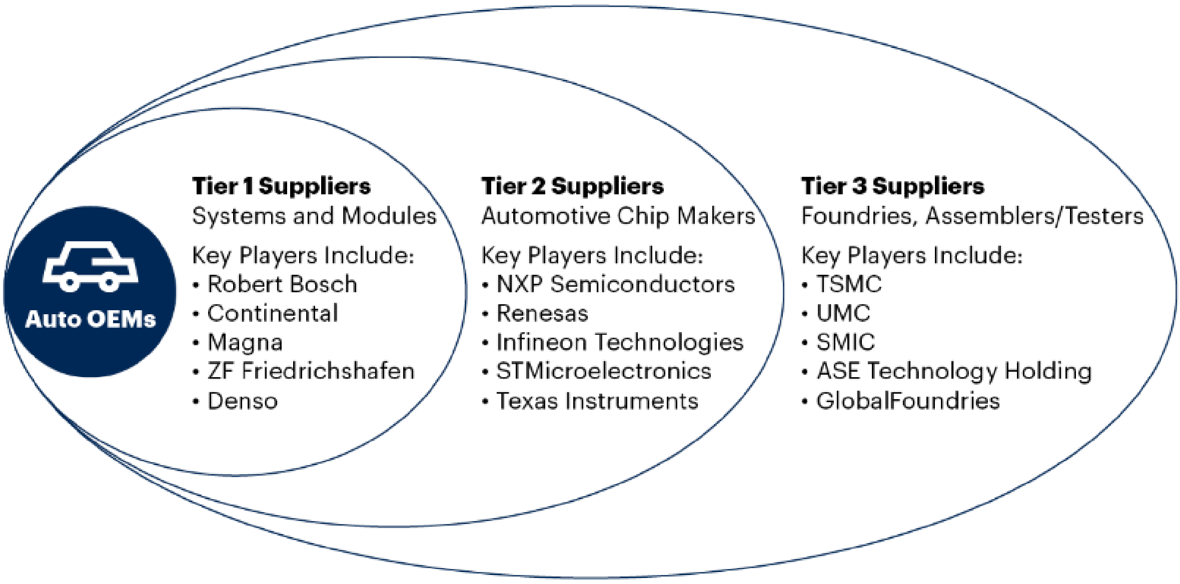
4.2 STRATEGIC ALLIANCE OF VOLKSWAGEN GROUP WITH STMicroelectronics

Like other automakers, to try to overcome the semiconductor crisis and secure a reliable supply in the future, the Volkswagen Group is adopting a strategy that provides a direct supply of chips years in advance. This is especially due to the fact that the increasing push towards the electric, will lead to a greater spread of electric cars, which require about twice as many semiconductors used in fossil-fuel-powered cars. Moreover, the European Union has decided to stop the sale of cars with gasoline and diesel engines. Among new cars, it will possible to sell only those that can guarantee zero emissions, such as 100%

electric cars, hydrogen fuel cells cars, or models that can be powered with synthetic fuels, but not with those derived from fossil fuels.

Another key issue is to gain more visibility of this long supply chain, typical of the automotive industry. The Volkswagen Group, through this new strategic alliance, is for the first time seeking to work directly with Tier 2 and Tier 3, to gain more control over its supply chain. As shown in figure 9, there are three tiers in the automotive semiconductor supply chain.

Figure 9: Tiers in automotive semiconductor supply chain



Source: Oliveira 2022

Tier 1 can be defined as the most technical, in fact it deals with the supply of the required automotive parts and systems directly to the car manufacturers. This is a particularly delicate step, since it is based on the just in time model, and, therefore, the companies belonging to this tier provide the exact number of components required by carmakers, at the time when they are requested. It is important that a Tier 1 company has good relations not only with its customers, but also with Tier 2 companies. In fact, Tier 1 firms keep the entire supply chain together, providing a link between Tier 2 and Tier 3 manufacturers, and end customers. The challenges facing a company, operating at this level, are related to the fact that it is crucial to the supply of customers, and to the urgency that is required. (Royale International 2022)

In the case of semiconductors, automotive companies purchase the required number of components, such as ADAS modules, Electronic Control Unit (ECU), or Telematic Control Unit (TCU), from Tier 1 companies, which in turn buy semiconductors from specialised companies that constitute the Tier 2 in the automotive supply chain. Some examples of firms operating in Tier 1 are Robert Bosch, Continental, Magna, ZF Friedrichshafen, Denso (Oliveira 2022).

Tier 2 is responsible for the creation of the components that will be integrated in the automotive parts or systems produced by Tier 1. As a rule, companies of this level purchase materials, such as metals and plastics, from Tier 3. These companies must follow strict protocols and adhere to high standards. (Royale International 2022)

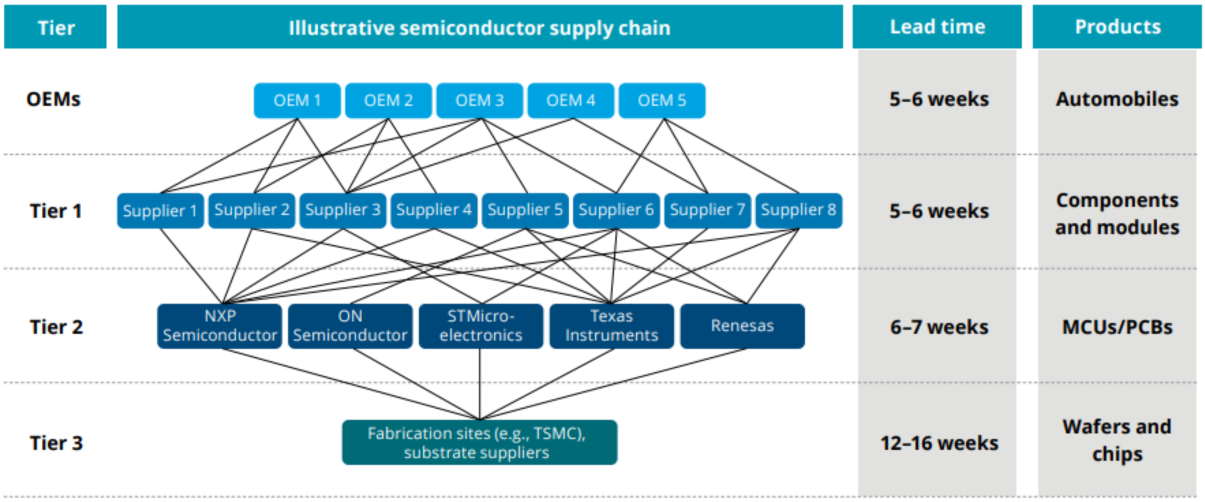
In the case of semiconductors, Tier 2 companies can be defined those which constitute the specialised manufacturers, that produce, for example, Microcontrollers, or System-on-Chip (SoC). Some examples of Tier 2 companies are NXP Semiconductors, Renesas, Infineon Technologies, STMicroelectronics, Texas Instruments (Oliveira 2022).

Tier 3 procures and supplies raw materials, and, therefore, without this level the whole system would collapse. The role of these companies is crucial, although they do not directly supply customers but only Tier 2. In fact, any issue at this level would impact the entire supply chain. (Royale International 2022)

For what concerns semiconductors, the companies that are part of Tier 3 are the foundries. Typically located in Asia, they produce wafers and substrates for the entire market, and therefore not only for the automotive industry but also for others. For example, TSMC, USM, SMIC, ASE Technology Holding, GlobalFoundries are part of this tier (Oliveira 2022).

In figure 10, it can be possible to observe, through the example of some companies, the complexity of the relations that are established between the various tiers of the supply chain of semiconductors.

Figure 10: The semiconductor supply chain network in the automotive industry



Source: Dutt, Khwaja, Richard 2021

For these reasons the Volkswagen Group has decided to form several strategic alliances with different companies, such as Onsemi, Qualcomm, and STMicroelectronics. In the following sections will be analysed the case of the alliance with STMicroelectronics.

Strategic alliance with STMicroelectronics

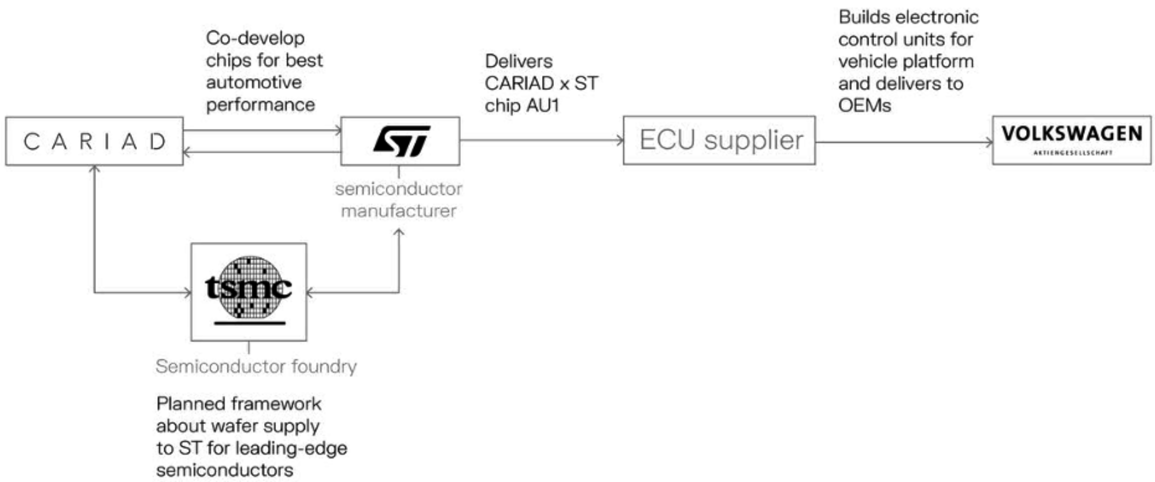
The strategic alliance between the Volkswagen Group (and in particular Cariad) with STMicroelectronics was born with the aim of co-developing new chips, which will be crucial in car models in future.

Cariad represents the software section of the Volkswagen Group, and it is responsible for bringing together, within the same multinational, the software skills of the entire Group, and expanding them further, creating a wealth of innovation for all brands belonging to the Group. Its mission is transforming cars into software-defined vehicles that integrate the automotive experience into costumer's digital life, turning the Volkswagen Group into a software-driven mobility provider. Cariad is not only a company part of the Volkswagen Group, but, in turn, it is a network of several companies. In fact, it has stakes in 15 firms that deal with technology applied to automotive, and that are specialized in different aspects of the digitization of cars. The company headquarter is located in Germany, and it is focused on the markets of Europe, United States, and China. (Cariad 2023)

STMicroelectronics is a semiconductor manufacturing company, and it is part of the IDM group, because it provides design, production, and delivery of products to customers. STMicroelectronics is based in Switzerland, but it is a global company. In fact, for what concerns front-end manufacturing, there are plants in Italy, France, Sweden, and Singapore. While, on the back-end manufacturing side, the plants are present in Italy, France, Morocco, Malta, Malaysia, China, and Philippines. Its mission is to be present whenever microelectronics makes a positive contribution in people's lives. The markets in which it operates are automotive, industrial, personal electronics, and communications equipment, computers & peripherals. (STMicroelectronics 2023)

Through the alliance with STMicroelectronics, the Volkswagen Group wants to reform its supply chain, ensuring the production of tailored semiconductors for the years to come. Figure 11 shows the strategy of the Volkswagen Group regarding the purpose of the alliance with STMicroelectronics.

Figure 11: Strategic alliance Cariad (Volkswagen group) and STMicroelectronics



Source: Cariad 2022

4.3 CHARACTERISTICS OF THE STRATEGIC ALLIANCE

It is important to place a greater focus on what are the characteristics and the purpose of this alliance. Moreover, it is crucial to analyse the factors of potential success and failure of this collaboration.

Scope of the strategic alliance

The purpose of the formation of the alliance between Cariad and STMicroelectronics is to jointly develop a new semiconductor, more specifically a System-on-Chip (SoC). It is a tailored hardware for connectivity, energy management, and over-the-air updates making vehicles fully software-defined, secure, and future-proof. The cooperation targets the new generations of models proposed by the Volkswagen Group, for the application of this new semiconductor. (Cariad 2022)

As shown above in Figure 11, the alliance provides not only the collaboration between Cariad and STMicroelectronics for the co-development of the component, but also an agreement with TSMC, a Tier 3 company, which is responsible for producing the SoC wafers to supply STMicroelectronics. The role of the Tier 1 suppliers of Volkswagen Group will remain the same, but they can use only the SoC co-developed between Cariad and STMicroelectronics. (Cariad 2022)

TSMC is a foundry that deals with semiconductor manufacturing for various end markets, such as high-performance computing, smartphones, the Internet of Things (IoT), automotive, and digital consumer electronics. Its mission is to be a reliable supplier of technology in the IC foundry segment of the semiconductor industry, now and in the years to come. The company is based in Taiwan, and owns several plants in this region, and it is known for having the technology that allows the production of the most advanced semiconductors. (Taiwan Semiconductor Manufacturing Company Limited 2023)

To summarize, the purpose of the alliance can fall into the category of reasons related to the skills enhancement, previously analysed in Chapter 1. The Volkswagen Group wants to ensure the supply of semiconductors for the next generations of its models, but it does not own skills and resources to produce the component in-house. Instead, STMicroelectronics wants to own the necessary software skills to further develop its hardware architecture, used in the production of the new semiconductor.

Type of strategic alliance

It is not yet clear what type of structure will be used in this strategic alliance; the two companies are talking only about co-development.

Advantages for Volkswagen Group (Cariad)

The main advantage of this strategic alliance for Cariad, and therefore for the Volkswagen Group, is to enter into a direct relationship with Tier 2 and Tier 3 for the first time. This is very important for two main reasons. First of all, the Group in the years to come ensures the exact production of the components it needs, at the exact moment this need appears. Working closely with Tier 2 and Tier 3 is particularly important to prevent future crises, such as the present one. In fact, this mechanism increases the visibility of the Group on its supply chain, avoiding that decisions are taken without carefully evaluating the potential risks associated, like that of drastically reducing the supply of semiconductors in 2020. Lack of supply chain visibility leads to situations where events, that lead to disruption in the supply chain, remain buried until it becomes too late to act. A limited exchange of information between tiers about who the suppliers are at the next level, what components they provide, and what risks could destabilize the whole chain, can lead to this type of crisis. (Dutt, Khwaja, Richard 2021)

Secondly, the close collaboration allows the realization of a component that is highly customized to the needs of the Group, and that is optimally matched with its software. This gives to the Group a great advantage, since it is possible to offer the best performance of its cars to the customers of the brands of the German multinational. In fact, using a common device architecture, it becomes less complicated for Cariad develop only one basic software for all Electronic Control Units (ECU), substantially reducing complexity and accelerating development. (Cariad 2022)

The choice of the partner

The choice of the partner, in this case STMicroelectronics, can be analysed under different aspects:

- complementarity of skills;

- compatibility of goals;
- cooperativity of cultures.

Starting from the complementarity of skills, Cariad has excellent abilities in the software field, while STMicroelectronics can boast great expertise in semiconductor design and production. In fact, as reported above in this chapter, Cariad is focused on creating a better car driving experience, thanks to the use of software. This improved experience translates into more safety and more comfort in driving the car. All this, it is based on the development of a single platform for all Volkswagen Group brands, which comprises an operating system, a unified architecture, and an automotive cloud. For what concerns STMicroelectronics, this company is among the best in semiconductor manufacturing, and works closely with many customers for the design and the building of products, solutions, and ecosystems that address their challenges and opportunities, and the need to support a more sustainable world. The company-owned technologies enable smarter mobility, more efficient power and energy management, and the wide-scale deployment of the Internet of Things and connectivity. It is therefore possible to confirm that between the two companies there is a kind of fundamental fit, necessary for the success of the alliance.

Secondly, another important point is that between the two companies there is a strategic fit, and therefore there is complementarity between the objectives of the alliance that they both desire. Also in this case, it is possible to state that this requirement is being met. In fact, Cariad's goal for the alliance is to ensure the supply of semiconductors for the next generations of Volkswagen Group models. While, the goal of STMicroelectronics is to co-develop a new semiconductor that adapts to the needs of Cariad, using its own Stellar architecture, and further developing it, by extending its power-efficient real-time capabilities to service-oriented environments. In this way the complementarity of the two goals will create an advantage for both companies, resulting from this alliance.

Finally, to ensure that the alliance is successful, it is important that the last requirement of complementarity between corporate cultures is also met. First of all, one fact to keep in mind is that the two companies are geographically close, since Cariad headquarter is located in Germany, while that of STMicroelectronics in Switzerland, both within the European Union. Many studies have shown that the culture of the working method in the company can vary greatly based on the country of location. When two partners are located in very distant countries the differences increase, while the culture is more similar if countries are close. In addition, it is possible to note a certain type of similarity in the two corporate cultures, regarding inclusiveness and attention to their workers. Cariad promotes a working environment in which inclusiveness and diversity are present in the profiles of their employees, and which offers everyone equal opportunities to grow. The same applies to STMicroelectronics, which defines people as the largest asset available to the company. It promotes a working environment that is first and foremost safe for workers, but also inclusive and open to diversity, looking for different profiles in the people being recruited, and giving the opportunity to expand their skills. There is a certain similarity also in the mission of companies, which aim to excel in their field, through continuous innovation. In fact, Cariad aims to transform cars into software-defined vehicles that seamlessly integrate automotive experience into customers' digital lives, building the leading technology stack for the automotive industry, with the aim of creating a new automotive experience and increasing the speed of innovation of the Volkswagen Group, to make the car a digital companion. While, STMicroelectronics aims to serve its customers through innovation, which brings a positive impact into their lives. It aims to create innovations and unique products that solve real-world problems through cutting-edge chip and packaging production technologies.

Management of opportunistic behaviour into strategic alliance

This strategic alliance has two distinct moments. The first concerns the development of a single project, with the co-development of the new semiconductor, more specifically a System-on-Chip (SoC). Then a second moment opens, which does not foresee a finite duration, in which STMicroelectronics will attend to the provision of the component for the Volkswagen Group, to the extent and in the time required, thanks to the supply of wafers by TSMC. In the first phase of the collaboration, which involves the development of a single project, the emergence of opportunistic behaviours is more likely once the cooperation part is completed. While, regarding the second phase, that it guarantees the supply of the component to the German Group, the opportunistic behaviours are more inclined to happen during the period of the collaboration. As described in Chapter 1, there are mechanisms that govern the emergence of these opportunistic behaviours.

In the first phase of the collaboration, it is necessary to concentrate on the initial step, the so-called collaborative/learning phase, in which the two companies will focus on producing information about them. To prevent this information from being used at the expense of the alliance failure, it would be necessary for the agreement to be based on two protection mechanisms. The first has the scope to favour the iterative investments in information, in this way the two companies define exactly what are the information to share with the other part, and which are the mechanisms of resolution. Since the first part is a co-development project, in which the aim is to create a component that adapts to the software used by Cariad, it is important that the company provides information related to this software, and at the same time, STMicroelectronics will also have to provide information related to its Stellar architecture. This will create a mechanism of mutual dependency, which will be strengthened even more in the second phase of the alliance. In fact, the Volkswagen Group will depend on the supply of the component from STMicroelectronics for the models of the future cars, but at the same time also STMicroelectronics will be able to sell that particular component only to the German Group, since it is built according to its needs. To make the alliance more secure, both companies could agree to adopt a contract referee mechanism. In this way, both companies would ensure that they do not misinterpret each other's behaviours, or produce information asymmetrically, that could benefit only one party.

In the second phase, that of the ongoing collaboration, the opportunistic behaviours can be fought thanks to the formation of switching cost, and to screening out naturally opportunistic counterparties. Starting from switching costs, the exchange of information that takes place during the first phase of the collaboration has led to the development of information costs. For both, Cariad and STMicroelectronics, the end of the relationship would lead to a loss of the efforts they made, and that should be duplicated with a new company. In fact, for Cariad it would be expensive and time-consuming look for a new partner that is able to adapt perfectly to its needs, and that can support a very high production of the new component, given the size of the Volkswagen Group. On the other hand, it would be the same for STMicroelectronics, as it should go to find a new partner specialized in the software field, which is able to further develop and make new improvements to its Stellar architecture. It could also lead to reputational damage. For example, if STMicroelectronics adopts an opportunistic attitude for which it would come to interrupt the collaboration, after having obtained the development of its architecture.

At this point other customers would be sceptical to enter into any kind of collaboration with STMicroelectronics. This would cause serious damage to the company, as it very often finds itself working closely with its customers to meet their needs. Although less likely, even Cariad, could decide, once the co-development phase is complete, to provide the information acquired to another supplier able to produce the component at a lower cost. Similarly, even in this situation, there would be reputational damage to the company, as suppliers will be more sceptical about collaboration, and in this way the Volkswagen Group may not be able to secure the supply of semiconductors. In addition, a second mechanism to reduce the possibility of alliance failure is to screen out naturally opportunistic counterparties. In this sense, both companies should pay attention to the way the other party cooperates, in terms of information sharing and dispute resolution.

Finally, it must be considered the last phase, the end stage. This is a phase to consider in the relationships that provide the development of a project, because it has a finished time. In fact, despite during the collaboration phase there was a symmetrical exchange of information, opportunistic behaviours can re-emerge at the time of the division of the gains deriving from the alliance. In the case of Cariad and STMicroelectronics, the alliance does not end once the co-development project is completed, and therefore the switching costs that have been created will continue to limit the emergence of opportunistic behaviours. However, it remains crucial that at the end of the first phase of the collaboration, both, Cariad and STMicroelectronics, have achieved the expected results.

4.4 COMPARISON BETWEEN VOLKSWAGEN GROUP AND TESLA

In the following section, it will be analysed Tesla's behaviour regarding the semiconductor crisis. This is to explain how not only the adoption of the strategic alliance is dictated by the context, but also by the characteristics of a company.

Tesla is a multinational company based in the United States (Texas), specializing in the production of electric cars, photovoltaic panels, and energy storage systems. In fact, its mission is to accelerate the world's transition to sustainable energy. In pursuit of this goal, it builds products that are designed to replace some of the planet's biggest polluters. Additionally, their energy generation and storage products work together with their electric vehicles to amplify their impact. So, it is not just a car manufacturer, it is also a technology company. (Tesla 2023)

Impact of semiconductor shortage on Tesla

In the three years after the onset of the semiconductor crisis, Tesla was not immune to this shock. In fact, it has undergone a brief closure of its plant in Fremont, in Northern California, in late February/early March 2021, and also it had delays in the production of its new Cybertruck. Despite this, the results shown by the company, in terms of sales, are amazing. In fact, starting in 2020, the company recorded total sales for 499,647 vehicles, an increase of about 35.9%, from the previous year. In 2021, Tesla achieved sales for 936,222 vehicles, up by 87.4%. Finally in 2022, the company showed sales for 1,313,851 vehicles, with a growth of 40.3%. (Shvartsman 2023)

How Tesla responded to semiconductor shortage

Despite the crisis that has affected almost all car manufacturers, Tesla has maintained and even increased its sale and production levels. This is thanks to some decisions and characteristics of the company, that allowed it to react quickly to the shock and mitigate the consequences. First of all, the company predicted that there would not be a large decrease in demand during the pandemic period. This is because buyers of Tesla vehicles proceed to purchase to possess some sort of status symbol, and therefore a bad economy may not lead to large swings in demand. For this reason, Tesla has not stopped supplying semiconductors during the period of COVID pandemic, as many other automakers have decided. (Finshots 2022)

Secondly, Tesla prefers to produce many components in-house, but when it decides to proceed with the purchase on the market, it goes directly to the manufacturers. It can be said that the company has a better relationship with suppliers than other car manufacturers, because there is a direct relationship without the involvement of third parties. (Finshots 2022)

Finally, Tesla was able to change the semiconductors that were used in its own cars, and replace them with others on the market that weren't hit by the shortage. This is due to the fact that the company is extremely technological, and its engineering team has rewritten the software needed to integrate alternative semiconductors. In addition, when the use of alternative semiconductors was not even possible, the company opted for a different strategy. The vehicles were delivered with missing parts, which were then added once the components became available again, or other components even eliminated. For example, some vehicles were delivered with missing USB ports, and front passenger-seat lumbar features were eliminated. (Loveday 2022)

To summarize, not only the context has led to the formation of strategic alliances with suppliers to combat the semiconductor crisis, but these are also due to the characteristics of car manufacturers. Tesla has been able to adapt to the changed environment, thanks to the fact that it can be considered a technology company, as well as a car manufacturer, and its greater vertical integration. In fact, many of Tesla's car components are developed in-house, and this has the advantage of being able to change their design quickly, in order to adapt them to that of the alternative semiconductors on the market. It is a company very focused on innovation, which is not based on traditional models of midcycle refreshes or complete redesigns. Instead, the company makes hardware changes when necessary, and in-vehicle software gets updated on a regular basis. In addition to this, it should be noted that the company has better control of its supply chain in case it relies on the market to purchase some components.

CONCLUSION

The goal of this thesis was to analyse the impact of the semiconductor shortage in the automotive industry, and to identify how most automakers organized themselves through the formation of strategic alliances. This collaboration strategy is used to prevent that in the future, a new shock in the semiconductor industry, can lead to a situation of crisis as heavy as the current one. In addition, it was important to analyse what are the factors of a potential success or failure of this type of strategic alliances, between suppliers and buyers.

The semiconductor crisis was the result of an extremely fragile and complex supply chain, which was hit by multiple factors. First of all, it is a long and complex chain because the semiconductor production process requires up to 1400 steps, and involves companies specialized in every single activity, located in a very large geographical area, especially Asia, North America, and Europe. This specialization of each individual company has advantages, but leads the supply chain to be vulnerable when disruptive events occur. In fact, the COVID pandemic and geopolitical tensions, especially between the United States and China, have brought considerable complications to this fragmented value chain.

Dozens of sectors have been affected by this crisis, but the absolute worst situation has been that of the automotive sector. It is especially due to the fact that the just in time method is used in this industry. This states that there will be no stock, but that the component, in this case semiconductor, will be requested from suppliers at the time and in the quantity in which it is needed, based on market demand of the final product. The result of all this has been that car production has suffered very heavy cuts, reaching 11.3 million vehicles in 2020, 7 million in 2021, and it is estimated 1.3 million in 2023. In addition to this drastic measure, many car manufacturers have been forced to remove some functions from their models. To address this problem in the future, a number of automakers, including General Motors, Stellantis, Ford, and Volkswagen Group, to name a few, have resorted to forming strategic alliances directly with semiconductor manufacturers, to secure the necessary amount of the component in order to meet the demand for cars in the market.

In this regard, the case study analysed was that between Cariad (Volkswagen Group) and STMicroelectronics. The reason that led both companies, to form this collaboration, is the fact that they want to get hold of skills they do not possess. In fact, on the Cariad side, the company want to seek expertise for the production of a semiconductor tailored to its needs, while on the STMicroelectronics side, the company sought a partner that could enhance its architecture.

There are many factors that make this alliance potentially successful. First of all, the choice of partner, because between the two companies results a complementarity of resources and knowledge, and, in addition to this, the two parties also have strategic objectives that are in harmony with each other. A second factor is the similarity between the two corporate cultures, which makes the process of managing people, within the team that will co-develop the new semiconductor, less prone to conflict, that can arise because of completely different working methodologies. A third factor is the fact that there is no overlapping between the market of the two companies, since the Volkswagen Group is mainly focused on the sale of vehicles, while STMicroelectronics on the sale of semiconductors, therefore there is no risk of competition between companies.

On the other hand, there are factors that can lead to the failure of the alliance. The wrong choice of partner, due to differences of corporate culture or strategic objective of the alliance, can be excluded among the factors that adversely affect this alliance, for what has just been said. Similarly, factors such as an incorrect expectation of the skills of the other partner or the failure of one of the two parties can be excluded, as these are leading companies in their field of expertise. The real risk relates to the occurrence of opportunistic behaviours from one party, in order to gain an advantage only for its own account, that conduct to the detriment of the other party. However, there are some mechanisms that can prevent the birth of these behaviours.

Finally, a comparison with Tesla was proposed, which did not find it necessary to form a strategic alliance with a semiconductor manufacturer. This can be explained by the company's own characteristics, which is among the factors that affect the use or not of this type of collaboration, as well as industry and external environment. In fact, Tesla is more vertically integrated, more innovation-oriented without relying on traditional production models, and it has more control over its supply chain than the Volkswagen Group.

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