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Investigating the drivers of semiconductor purchases in the Aveiro district in a post-pandemic period

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INVESTIGATING THE DRIVERS OF SEMICONDUCTOR
PURCHASES IN THE AVEIRO DISTRICT IN A POST-PANDEMIC
PERIOD

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Acknowledgments

Throughout my life, I've faced several challenges, some of which I chose and others that were beyond my control. These events have transformed me into a person with more resilience, determination, and a positive attitude in life.

Obtaining my master's degree is one of the most significant challenges I've faced. This is attributed primarily to three major factors: First, I intentionally moved outside of my comfort zone and confronted the language barrier head-on. Second, I began this trip with a significant lack of core economics and management knowledge. Third, I did a master's degree in student work systems.

Due to the circumstances mentioned above, I'd want to thank those who have helped me along the way, particularly PECOL Sistemas de Fixação for their flexibility, my advisor, Pedro Neves, who, despite not approaching him very often, has always demonstrated patience, availability, and interest in supporting my theme. To my family, friend João Camarneiro for his English assistance and suggestions, Manuel Camarneiro for his technical knowledge and patience, and my girlfriend, Raquel Teixeira, for the recommendations to keep me more organized.

Finally, I want to thank the FEP for stimulating my interest in subjects that before had not pushed me to stop and look deeper.

ABSTRACT

In China, a critical turning point arose near the end of 2019. The start of the pandemic triggered a significant shift in how economic actors behaved both economically and socially. This period sparked an assessment of the concept of globalization, leading politicians and business leaders to recognize the extent of Western economies' reliance on Asian nations as China and Taiwan, particularly in terms of semiconductor supply.

This was the first step in recognizing the key adjustments in purchasing behavior among Portuguese enterprises, especially those in the Aveiro District, who use semiconductors in their manufacturing processes. The goal is to determine whether there has been a shift in the variables affecting purchases and whether corporations are implementing innovative approaches to reduce their dependency on the Asian market.

The findings indicate notable alterations in the factors influencing the procurement of semiconductors, particularly within multinational corporations. However, smaller and medium-sized enterprises hold the view that the drivers remain unchanged, with cost being the paramount determinant in their decision-making process.

Regarding strategic shifts within corporations, the observations indicate that only multinational businesses are adopting new strategies into their business. These alterations include internalizing semiconductor manufacturing and increasing investments in R&D departments.

KEYWORDS

Semiconductors, purchase drivers, supply chain, pandemic, globalization, internalization

RESUMO

Nos finais de 2019 surge um ponto de viragem marcante que teve origem em território chinês. O início da pandemia desencadeou uma mudança importante na forma como os agentes económicos operavam, em contexto económico e social. Durante este período, políticos e líderes empresariais, passaram a reconhecer a elevada dependência das economias ocidentais, nos mercados asiáticos, nomeadamente China e Taiwan, especialmente no fornecimento de semicondutores.

Este acontecimento contribui para várias alterações no comportamento de compra das empresas portuguesas que incorporam semicondutores nos seus processos de fabrico, especialmente no distrito de Aveiro. O objetivo deste estudo é determinar as eventuais mudança nas variáveis que influenciam a compra destes componentes e se as empresas estão a implementar abordagens inovadoras para reduzir a sua dependência do mercado asiático.

Os resultados indicam alterações nas variáveis que influenciam a compra de semicondutores, particularmente nas empresas multinacionais. No entanto, PME's do distrito consideram que os fatores se mantêm inalterados, sendo o custo o principal determinante no seu processo de decisão.

Relativamente às mudanças estratégicas nas empresas, os resultados sugerem que apenas as empresas multinacionais estão a adotar novas estratégias nos seus negócios. Estas alterações incluem a internalização da produção de semicondutores e o aumento dos investimentos em investigação e desenvolvimento.

PALAVRAS-CHAVE

Semicondutores, variáveis de compra, cadeia de abastecimento, pandemia, globalização, internalização

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1. INTRODUCTION

The semiconductor industry is a crucial driver of economic competitiveness in today's world, by driving innovation and advancement across a wide range of areas, such as digital transformation, artificial intelligence, and 5G communications (Varas et al., 2020). Semiconductors, as the backbone of technological innovation, power everything from innovative electronics to critical infrastructure. However, the vitality of this industry has raised worries about over-dependence on external sources, particularly the US, South Korea, Taiwan, and some European locations, while much of the production, testing, and assembling takes place in China (Grimes & Du, 2022).

The pandemic was a milestone point, highlighting the importance of preserving critical supply lines and promoting self-reliance within the European Union.

These market circumstances motivated both the European Union and the United States to invest significant efforts to improve domestic chip manufacturing capabilities. Among these measures is the announcement of multibillion-dollar subsidies aimed at increasing production capacity to reduce dependency on external sources.

As a result, this research aims at examining to which extend organizations have modified their operating strategies in response to the identified constraints. These challenges include continuous semiconductor shortages, prolonged lead times, and the development of new suppliers as viable alternatives. In response to these issues, some companies have adopted new ways to avoid such unpredictable events. For example, Bosch announced a 1 billion euro investment in new semiconductor infrastructure in Dresden, Germany.

The combination of those factors, as well as my interest in the subject, inspired the selection of the project's theme. The aim is to determine whether purchasing motivation has undergone any changes in the aftermath of the pandemic in Aveiro district, Portugal.

This study begins with a complete market analysis of both the global and Portuguese semiconductor markets. With a focus on the Portuguese market, special emphasis was given to analyzing the trade balance, identifying semiconductor categories with high demand, and determining the countries of origin. These observations were essential in developing the interview structure.

Following that, an examination of the operational dynamics of the supply chain was conducted, followed by an investigation of the patterns influencing worldwide purchasing

behaviors. The investigation then dives into the history of vertical and horizontal strategies in the semiconductor business. Finally, the study goes into the driving variables that drive purchase department decision-making.

The following section goes into the qualitative methodology used. To ensure more comprehensive market descriptions and to uncover purchase motivations beyond those identified in the literature review, the data collection approach centered on interviews. Five interviews were done, one of which was with a significant figure in an important distribution firm of this components.

Following that, it will be presented and discuss the results of the research. According to these findings, over half of these organizations are currently making strategic adjustments. They also confirm that there has been a significant shift in the variables driving semiconductor purchasing within businesses, particularly from the time of the pandemic to the present.

2. LITERATURE REVIEW

2.1 Market Overview

To effectively analyze the market, it is crucial to distinguish between what qualifies as a semiconductor and what does not. There are active, passive components, and electronic integrated circuits (EIC). Any component within a circuit that can regulate and direct the movement of electric charges is referred to as an active component or semiconductor device. On the other hand, passive components are circuit elements that cannot actively control or regulate the flow of electric current through an external electrical input (Kuphaldt, 2009).

An integrated circuit (IC), also referred to as a chip, is made of silicon, a semiconductor material. Tiny electronic components known as transistors are produced within this silicon substrate. These transistors are intimately interconnected through layers placed on the silicon's surface (Akanksha, 2023)

Following this enlightenment, the next two sections provide us with a quantitative perspective on the importance of the semiconductor industry in the international and Portuguese markets.

2.1.1 Global Market

Since 1987, when its market worth was \$33 billion, the global semiconductor sector has registered significant and constant growth. By the turn of the century, the value had risen to \$205 billion, and it had recently reached \$440 billion in 2020. The statistics demonstrate the impact of digitalization on society and the dependence of individuals on different kinds of electronics, increasing demand for such goods (Alsop, 2023).

More recently and despite the market volatility triggered by the pandemic, the global revenue generated by the semiconductor industry increased by 1.1% to reach \$601.7 billion in 2022. The top 25 semiconductor suppliers, which accounted for 77.5% of the total market, had a 2.8% growth in sales in 2022 (Howley, 2023)

Table 1 provides information about the main suppliers in this market, specifically, the top 5 producers ranked by revenue (measured in millions of US dollars), as well as their respective market shares from 2021 to 2022.

Table 1*Top 5 vendors ranked by revenue (millions of US dollars)*

Rank	Vendor	Revenue 2021 (\$)	Revenue 2022 (\$)	Market Share 2022 (%)	2021-2022 Growth (%)
1	Samsung Electronics	73.197	65.585	10,9	-10.4
2	Intel	72.536	58.373	9,7	-19.5
3	SK Hynix	37.192	36.229	6,0	-2.6
4	Qualcomm	27.093	34.748	5,8	28.3
5	Micron Technologies	28.624	27.566	4,6	-3.7
Others		356.310	379.193	63	6.4

Note: Own elaboration. Source: Howley, 2023

Despite a 10.4% decline in revenue in 2022, Samsung Electronics remained the leader in the market. The decrease in revenue was mainly due to a decline in sales of memory and NAND flash (storage technology commonly used in electronic devices). Meanwhile, Intel maintained its second position in the market, with a 9.7% market share. The company's overall revenue growth experienced a decrease of 19.5%. Andrew Norwood, in a statement provided to a Gartner press release, highlighted that at the outset of 2022, there was a shortage of semiconductors. This scarcity resulted in prolonged delivery periods and escalated prices driven by speculation. During the latter half of the year, the economy began to display initial signs of deceleration, attributed to factors such as elevated inflation, interest rates, energy costs, and persistent lockdowns in China, all of which had an impact on the complete value chain (Howley, 2023).

Due to the market scope, it's pertinent to divide and analyze the market into two categories: memory devices and nonmemory devices such as analog, discrete, and so on. Memory devices account for 25% of semiconductor sales in 2022. However, 2022 registered a decrease of 10% compared to 2021. The underwhelming performance resulted in an oversupply of these devices. To stabilize the market, manufacturers took action by cutting down both production and the inventories of semiconductors (Howley, 2023).

Despite some uncertainty, the industry is expected to experience significant growth as a result of a higher demand caused by remote working, artificial intelligence, and electric

vehicles (McKinsey & Company, 2023). According to the same source, the main segments responsible for such output will be automotive (due to increased demand for electric mobility), computation and data storage, and wireless.

In terms of market value, the prediction is one trillion dollars by 2030, representing a 66.2% growth over 2022 values. (McKinsey & Company, 2023). Alsop (2023) supports this estimate and also suggests that the primary areas of application for semiconductors will be servers, data centers, storage, automotive, and industrial electronics.

2.1.2 Portuguese Market

Regarding the Portuguese market, the Boletim Mensal de Economia Portuguesa (BMEP, 2020) examined the Portuguese economy's imports and exports of machinery and computer units, which included semiconductors. The nominal values shown are the cumulative values from January to July 2019 and 2020. These two periods are important because they represent the post-pandemic phase in 2019 and the first months of lockdowns in 2020.

The first conclusion was the trade balance deficit for machinery and informatic units, semiconductors devices, and integrated electronic devices. Between January 2019 and July 2020, these imports accounted for 3.1% of total imports, while exports accounted for only 1.4%.

Despite this, this market has seen a considerable increase in the annual growth rate of exports of 331.8% from 2015 to 2019, compared to imports which increased by 203% in the same period. In terms of nominal value, semiconductor imports are more significant in the trade balance than exports (BMEP, 2020).

Table 2 provides information on the changes in the trade balance between the post-pandemic period (2019) and the early months of the pandemic (2020).

Table 2*Trade Balance - Semiconductors Devices (million euros and percentage)*

	January to July		
	2019 (€)	2020 (€)	Variations (%)
Imports	317	178	-43,8
Exports	157	103	-34,3
Balance	-160	-75	-53,1

Note: Own elaboration. Source: BMEP (2020)

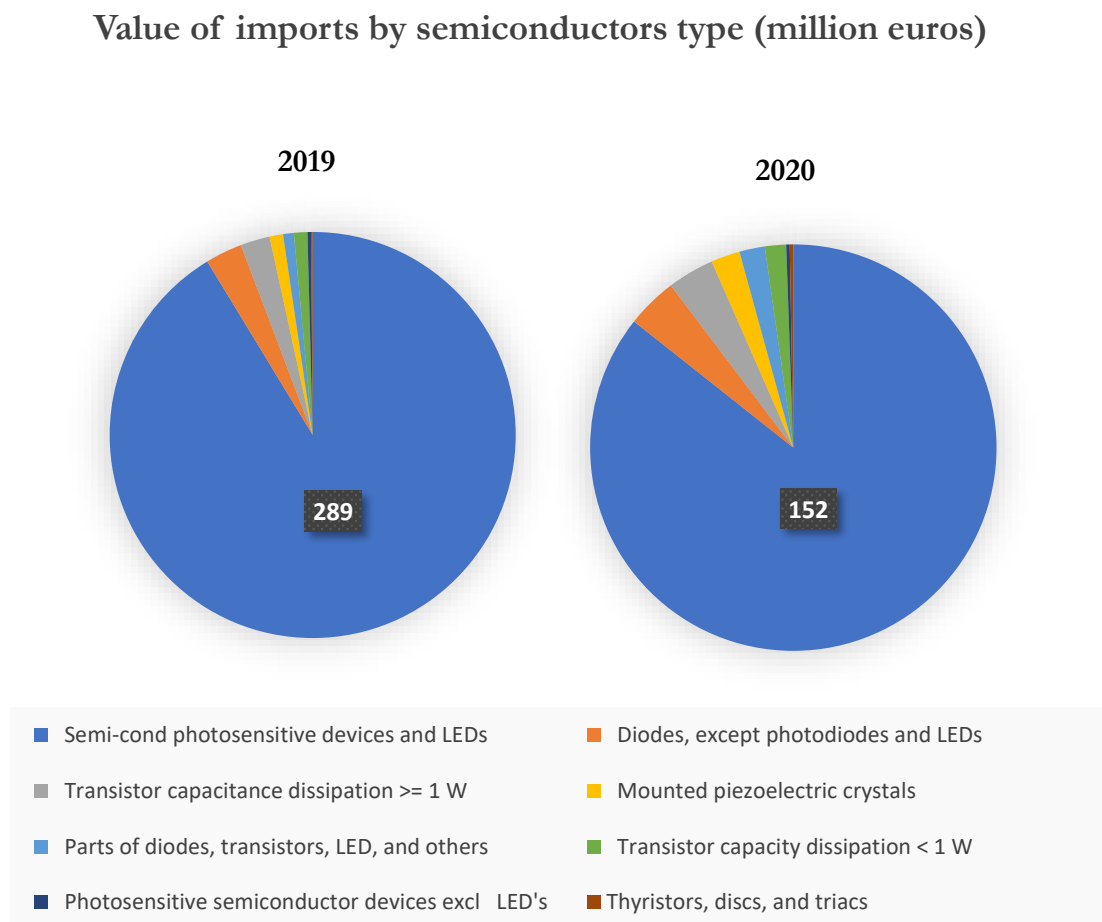
The table above shows how reliant the Portuguese economy is on the international markets. According to the data, the trade balance for semiconductor devices in 2019 was -160, meaning that imports surpassed exports in value. Moving forward to 2020, both imports and exports decreased, resulting in a balance of -75. This fall, equivalent to a 53.1% contraction, was principally driven by a larger nominal reduction in imports as a result of pandemic-related lockdowns (BMEP, 2020).

Considering the complexity of this industry, it is relevant to analyze more deeply the specifications of the semiconductors. The first thing to retain is that there are semiconductors that require more technology and expertise, while others are more standardized and easier to produce (Grimes & Du, 2022). That particularity influenced the country of origin of these materials. For this study, it's more important to evaluate imports rather than exports, as well as the types of semiconductors that have a substantial preponderance on the total amount of imports.

As a result, the following figure shows the nominal value of semiconductor imports in millions of euros from January to July 2019 and January to July 2020. These distinct periods correspond to the post-pandemic and current-pandemic phases, respectively.

Figure 1

Value of imports by semiconductors type (million euros)



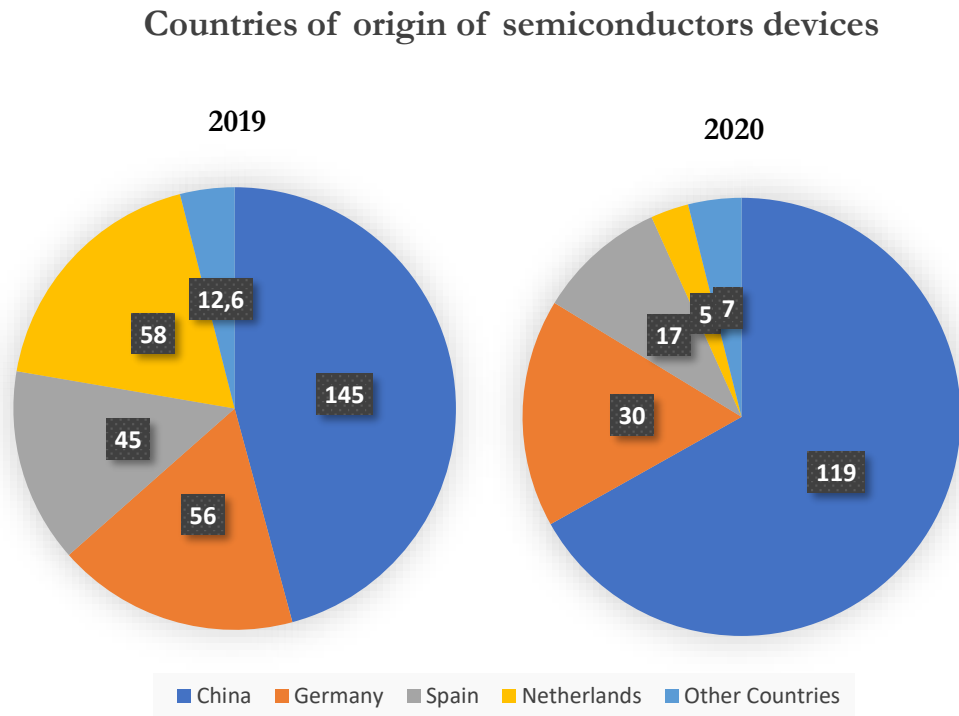
Note: Own elaboration. Source: BMEP (2020)

Semiconductor photosensitive devices and LEDs had a substantial effect on total imports, accounting for 289 million euros in 2019 and 152 million euros in 2020. In 2020, these types of semiconductors accounted for approximately 86% of total import value.

Figure 2 shows the countries of origin of the semiconductor devices in the same periods that were already mentioned in the last illustration.

Figure 2

Countries of origin of semiconductors devices (million euros)



Note: Own elaboration. Source: BMEP (2020)

Figure 2 shows that China leads the Portuguese market as the primary supplier of semiconductor devices. Between January to July 2020, Portugal imported a total of 119 092 million euros from China. This figure was 17.8 percent lower than the same period in 2019. Taiwan, on the other hand, led in Electronic Integrated Circuits (EICs) with 138 022 million euros, followed by Germany with 129 292 million euros during the same period. In contrast to semiconductor devices, EICs experienced a 2.7% increase in demand. According to Pennisi ((Pennisi, 2022)), this increase can be linked to the country of origin of these components. Taiwan, unlike China, did not adopt similar COVID-19 policies. Consequently, during the initial months of the pandemic, they were able to follow the higher demand for EICs.

2.2 Supply Chain Overview

Before analyzing the semiconductors supply chain it is important to clarify several features related to these devices. They can be used for memory, logic, analog, discrete, optical

components, and sensors, and, as a result of the manufacturing complexity as well as the location, producers tend to focus on just one segment. On the other hand, the firms that integrate this component in their production process tend to require all types of semiconductors, so they may work with different suppliers. (Burkacky et al., 2022)

The process of producing chips is more sophisticated and involves multiple steps, including obtaining materials, multiple manufacturing phases, and finally, back-end manufacturing. Companies usually specialize in three steps or less and may hire outside partners for tasks such as assembling printed circuit boards. After the back-end manufacturing, the chips become a part of the electronics production chain (Burkacky et al., 2022).

The same author suggests that the high level of complexity and specialization among semiconductor producers leads to a significant degree of interdependence throughout the value chain. No single local market can fully design and manufacture semiconductors from start to finish. Consequently, producers often collaborate and pool their resources and expertise to keep costs down.

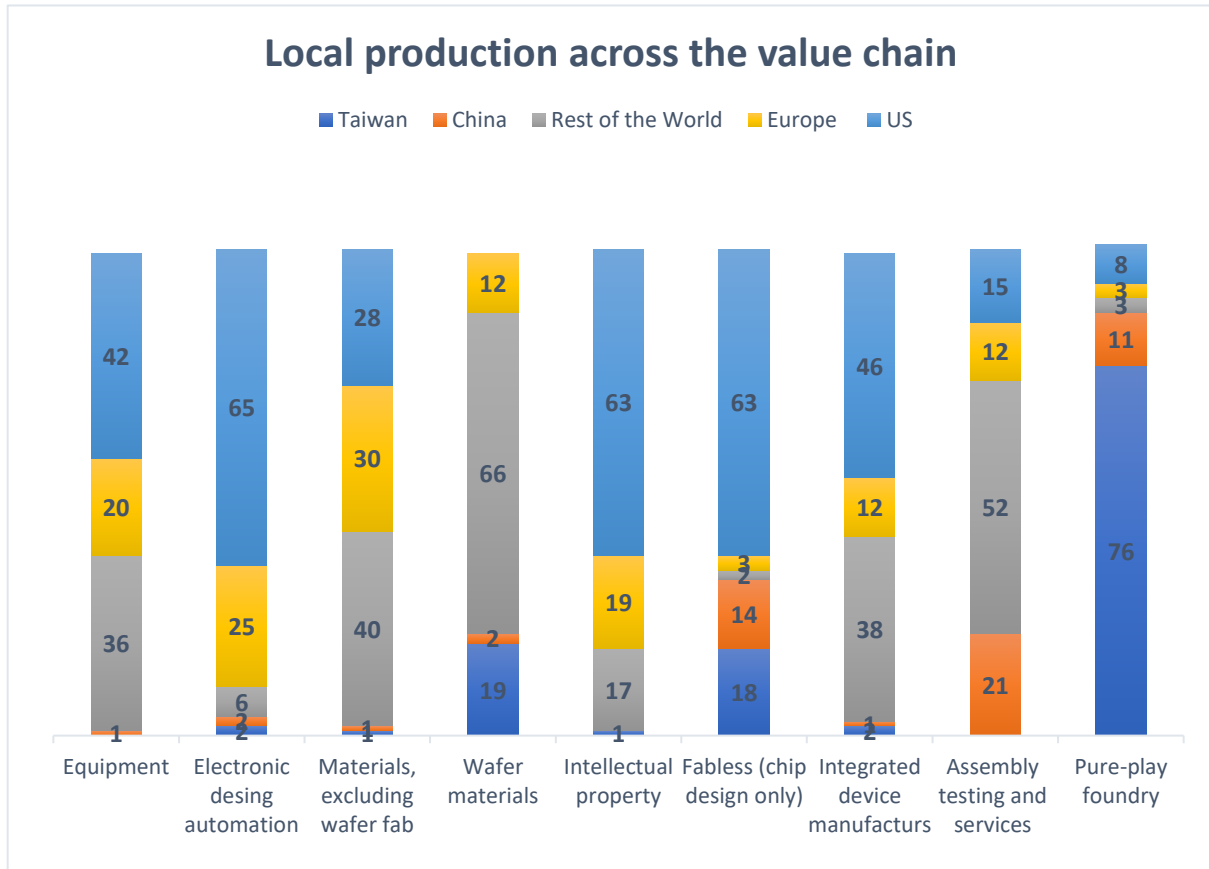
Macher & Mowery (2004) also mention that the vertical integration strategy has brought more economies of scale, but it required more capital to invest in more efficient ways to produce, and the short product life cycle brought a lot of uncertainty for producers. That's the reason why it's challenging for later companies to aim for a relevant position in the market.

However, this interdependence also means that any disruptions or shocks in the local market can have a ripple effect that impacts the entire global value chain (Burkacky et al., 2022)

The figure below shows how local semiconductor production is distributed across the value chain, as well as the disparities in some of the production phases.

Figure 3

Distribution of semiconductor production across value chain (%)



Note: Own elaboration. Source: (Burkacky et al., 2022)

Looking at **Figure 3**, we can see that the United States has a greater degree of control over various stages of the value chain, particularly in areas such as electronic design automation, intellectual property, chip design, and integrated device manufacturing. According to Grimes & Du (2022), countries like South Korea, Taiwan, and some European countries are also credible producers in this value chain phase. Assembling is commonly ensured by Asian countries, particularly China.

A key player in the value chain is Taiwan Semiconductor Manufacturing Company (TSMC) which is a company in Taiwan that plays an important role in the pure-play foundry of semiconductors. This company works with clients with the most advanced process technology in the world and adopts specialized strategies over the entire value chain. In 2022, TSMC held over 53% of the worldwide foundry industry, while Samsung only had 17% whereby Taiwan had control over 76% of the market (Kamal, 2022). This means that there is a high level of dependency on a single player in the semiconductor pure-play foundry. That's the reason why China is trying to follow the same steps as Taiwan and South Korea

by targeting memory devices as a way to enter the market. It has, nonetheless, been unsuccessful so far until this point. (Grimes & Du, 2022)

As a result, TSMC has a crucial role in preventing stockouts around the world and it's a key player in the normal operation of the value chain. In response to concerns raised by the United States about the impact of the chip shortage on various industries, TSMC has taken action to address the issue. TSMC announced the building of a new chip plant in Arizona for \$12 billion. This plant will begin producing 5 nm chips by 2024, which will help to alleviate the chip shortage and improve the overall supply chain for the semiconductor industry (Burkacky et al., 2022).

According to the same source, despite recent government investments in rebuilding the European semiconductor industry, market participants remain pessimist about the value chain's evolution.

2.3 Purchase behavior across the globe

The purpose of this research is to examine the consumption trends in the Portuguese market. Considering the lack of research on the subject, the following section attempts to examine the growth of global industrial purchasing drivers as well as the impact of the pandemic on the supply chain and how firms make procurement decisions.

According to Wright, vice president and general manager of Integrated Solution International, just 20% of European corporations bought directly from suppliers (data from 1997), although France has a higher propensity to buy directly from the source and less through distributors (Wright, 1997). A study from Electronics Weekly (2003) confirms that France is running away from the trend of the other countries of the European Union which is buying from distributors (Wilson, 2003).

According to the same source, each country chooses to purchase from a restricted number of providers. National Semiconductors and Texas Instruments, for example, are the most common manufacturers in Germany, although France, the United Kingdom, and Scandinavia have a distinct range of suppliers.

Considering the trend to buy this good through a distributor, the most notorious companies are Farnell and RS Components. Although there are other well-known

distributors such as Arrow (very common in Germany), Future, Silica, EBV Elektronik, and Anglia Components (Wilson, 2003).

During the pandemic, there was a shortage of semiconductors in all companies that use electronic devices in their assembly lines. The automobile industry was the first to be affected; manufacturers such as Volkswagen, BMW, Jaguar, and others made public pronouncements about this crisis, and some were forced to temporarily close their factories due to a shortage of these components. (Saran, 2021).

Electronic producers were also affected, but the issue that had the greatest impact on them was the increased demand for electronic devices and cloud services. This phenomenon was caused by the lockdowns and home office telework, practices that were quickly adopted all over the world (Saran, 2021). However, in 2022 the paradigm changed, and families and companies started to reduce the bills in electronic devices which resulted in moderate growth in this period (Howley, 2023).

Furthermore, higher inflation rates, rising interest rates, higher energy prices, and successive Chinese lockdowns all had a detrimental impact on slower market growth. (Howley, 2023). A McKinsey article explaining "What is a semiconductor" identified five additional reasons for this shortage (2023):

- Industry is operating at 95% capacity.
- The long periods to build new facilities, because of the huge monetary investment and the business complexity.
- US sanction to China which convey to long delivery periods and more pressure on other manufacturers
- Semiconductor manufacturers are forced to supply companies with long-term contracts, resulting in longer delivery times for short-term contracts.
- The appearance of 5G technology, which requires the same semiconductors as the automotive industry.

In addition to the reasons stated above, Howley Catherine (2023) mentions that OEMs (Original Equipment Manufacturers) have implemented further measures to prevent supply chain disruption by stockpiling an excess quantity of semiconductor chips (2023)

To meet the high demand and reduce Asian dependency, the largest global producers are making significant efforts to increase their production capacity. However, this endeavor requires a greater amount of energy, water, and raw materials. To put this into perspective,

by 2030, the consumption of energy in the production of chips alone will account for 20% of the world's energy consumption, and the largest producers could use up to 38 million liters of water per day in the fabrication process (Alam et al., 2023)

According to Saran (2021) report, companies are striving to conserve water and to conserve new sources of water in response to the increased demand and consumption of water in production. Furthermore, 37% of executives in the semiconductor industry believe that sustainability will play the largest role in shaping the industry's future, and 94% of these executives view such changes as having a positive impact on profitability (Alam et al., 2023).

To conclude, the semiconductor value chain will face numerous challenges during the next two years, according to an Accenture study. Inflation and economic concerns were cited as the top concern by 35% of Executives, followed by persistent COVID-19 effects (20%), a shortage of skills (18%), a lack of investment (14%), and finally geopolitical issues (12%) (Alam et al., 2023).

2.4 Vertical and Horizontal Strategies in the Semiconductors Industry

Throughout the history of the computer industry, major companies started to design and produce their electronic components by adopting a vertical integration strategy. In recent years, companies began to buy from specialist suppliers as a result of the introduction of new and more complex microprocessors (Malerba et al., 2008).

Recently, decision-makers have begun to ponder the idea of aggregating the production of semiconductors to their existing business as a way of reducing their dependency on suppliers (Cunha, 2019). This make-or-buy dilemma is the most difficult decision that decision-makers face today. There have been numerous studies on this subject throughout the years, and none of them are conclusive regarding what is the best decision.

This concept is referred to as plural sourcing, a practice commonly observed in multinational enterprises like Lego and Toyota. The rationale behind adopting a plural sourcing strategy is for companies to acquire enhanced expertise in product manufacturing, consequently leading to the cultivation of stronger competitive advantages (Cunha, 2019).

In recent times, a McKinsey article discussing "Strategies to lead in the semiconductor world" indicates that the scarcity of semiconductor chips is emerging as a

critical issue. This shortage is compelling major tech companies and car manufacturers to take matters into their own hands by internalizing chip design. However, this move could potentially lead to significant adverse effects on the semiconductor sector (Burkacky et al., 2022). The study “The pulse of the semiconductor industry” from Accenture, suggests that companies are prioritizing the preservation of innovation and making efforts toward deglobalization (Alam et al., 2023). This is evident from Bosch's recent announcement of a significant investment of 1 billion euros in new facilities located in Dresden, Germany. The primary objective of this investment is to integrate electronic components into electric tools and subsequently expand production for the automobile sector (Rocha, 2021).

This new trend of transferring semiconductor production to the West was reinforced by political concerns. The United States and the European Union have announced multibillion-dollar programs to boost their respective domestic chip production (Browne, 2023). Executives anticipate that geopolitics will play an even greater role in semiconductor innovation in the future (Alam et al., 2023).

Even though expanding or building new facilities can significantly increase production, this process typically requires a significant investment of both time and money. In general, a year or more is needed for significant expansion, while building a new facility can take more than three years, making it impractical to rapidly increase production (Kamal, 2022)

2.5 Motivation drivers behind the purchases departments

According to Saaty and Kartz (1990), businesses must identify and assess the many elements that influence purchase decisions. Understanding these elements is critical for the company to examine and select the most effective options available in a creative manner.

The buying process, according to Serrano et al. (2018), may be split into four stages: planning, data collection and analysis, performance review, and improvement. These steps enable managers to be more forceful when deciding whether to use insourcing, outsourcing, or a multi-sourcing approach.

When the decision-makers are in the middle of a make-or-buy dilemma, they consider several factors to select the best alternative. The first and most important is cost, as companies are more likely to choose the option that gives the greatest cost savings (Serrano et al., 2018).

However, the same source suggests that the cost shouldn't be considered separately. As a result, decision-makers should evaluate the risk of core capabilities, strategy, market instability, flexibility, capital requirements, financial rewards, and know-how, before making any decision.

Faber et al. (2007) suggest that several factors must be considered by the purchaser and that must be classified according to the complexity of the product. As a result, they should evaluate the technical, commercial, logistic, and administrative dimensions, and define which is more critical for the business.

Besides that, the purchaser should be aware of the infrastructures and logistic chain of the country of origin. The author mentioned India as a good example of a country with several concerns about transportation, which makes it a non-attractive supplier for modern demand. Another aspect mentioned is the data communication with the supplier. The ones that don't invest in these communication tools aren't attractive to purchasers (Faber et al., 2007).

The same author states that buyers are under a lot of pressure as a result of market dynamism. They must manage low inventory levels, make more decisive supplier selections, build and maintain strong supplier partnership ties, and target suppliers who show a high level of commitment to the client's business.

Considering the central theme of this study which is understanding the main factors that motivate the purchase of semiconductors in Portugal, the next paragraphs will shed some light on how the recent literature has addressed this issue.

A survey conducted for the Electronics Weekly magazine addressed 400 decision-makers from several companies that buy analog semiconductors in the UK, Germany, France, and Scandinavia. The first drawn conclusion was the optimistic perception of participants, which believed that they would increase sales in the following 6 months (Wilson, 2003). Today, decision-makers' positive outlook is also a reality.

The availability of the goods is one of the most crucial factors for the buyer. The majority of them utilize this metric to judge the supplier's quality. This characteristic makes local suppliers more appealing than foreign suppliers (Wilson, 2003).

However, depending on the component complexity, other aspects should be addressed. The most important aspects (from most to least important) are quality (26% of the votes), product availability (26%), price (21%), technical standards, and technical

assistance. More than 80% identify product quality as an important aspect, and 70% identify delivery time as a critical factor in this decision-making process. Yet, the relevance of lead time is linked to the shortage of semiconductors; when there's a market shortage of this good, the lead time becomes more important to purchasers (Wilson, 2003).

The same study suggests that these characteristics may differ based on location; for instance, France emphasizes technical support as a key factor with greater importance than the other countries' assessment in the study. Approximately one-third of those questioned in France believe this is an essential factor. Aside from that, there are other aspects relating to human preferences that are difficult to assess and differ from one buyer to the other.

Cultural factors can also play a role in shaping human preferences. According to a 2005 study published in the *Journal of Operations Management*, cultural connections are crucial for enhancing commercial and technical support (Petersen et al., 2005).

According to a survey among 150 Polish firms from various industries (automotive, electromechanical, and chemical sectors operations), there are six criteria to evaluate a supplier to reduce purchasing risk. The study takes into account the product's quality (defectiveness), delivery time and flexibility, time to restore delivery continuity, support documentation, and pricing competitiveness. Another emerging criterion among firms is the requirement for a supplier to have a sustainable environmental policy, such as practices that foster a reduction of dangerous goods, less energy and raw materials waste, and reduced gas emissions (Urbaniak, 2021).

3. METHODOLOGY

The research question is whether the drivers of semiconductor procurement in organizations changed after the pandemics, from the standpoint of decision-makers, buying managers, or even a semiconductor sellers. The investigation of this subject was motivated by the increasing importance of semiconductors in driving technological advancements, the impact on the operational costs of companies integrating these components into their production, as well as the significant disruptions experienced by the value chain during and after the pandemic, and the existing gap in academic research.

As a result, the aim is to determine whether purchasing motivation has undergone any changes in the aftermath of the pandemic in the Aveiro district, Portugal.

The choice of this region was based on the reasonable number of organizations that buy semiconductors, as well as their proximity, which allows us to reach the decision-makers more effectively.

3.1 Semi-structured interviews

Considering the theme's complexity, a qualitative methodology was chosen because it provides detailed descriptions of the market, identifies purchase patterns, and allows for "why" questions that contribute to describing the information in detail (Ritchie & Lewis, 2003). This makes it easier to analyze the motivations behind purchase behavior.

To accomplish this goal, an exploratory study was conducted using a semi-structured qualitative interview technique with four decision makers/purchasing managers from firms that buy semiconductors and one seller of one of the biggest distributors in the Iberian Peninsula. The selection of one seller is based on his industry expertise (15 years of experience) and his strong sensitivity to the structural changes that are emerging in this industry.

The data collection method adopted – interviews – is justified by its ability to provide detailed and in-depth information about the perspective and experiences of the interviewees about the semiconductor buying process (Ritchie & Lewis, 2003), allowing a more complete and richer understanding of the phenomenon in question as well as a detailed understanding of how this industry operates in the pre-pandemic and post-pandemic period. Besides that, Moriarty (2011) added that it is a more familiar and flexible way to collect opinions and experience and provide a large amount of data in each interview, which should last between 1 and 2 hours. Given the nature of the interview questions - which focused on strategic topics in a corporation - interviews were the ideal data collection approach.

The interviews were carried out individually, at a place previously agreed upon with each interviewee, with an average duration of one hour. Semi-structured scripts were prepared to guide the questions but allowed some flexibility for the interviewees to explore emerging themes during the conversation. The interviews were recorded and later transcribed for analysis.

In summary, the semi-structured interview methodology adopted in this study were enable a deeper understanding of the semiconductor purchasing process in firms from the perspective of decision-makers/purchasing managers. Furthermore, the analysis of interview

transcripts will provide vital insights and support purchasing strategies in the future by providing important insights about market drivers.

The table below shows the interview script as well as the expected information for each question or set of questions to respond to the study issue.

Table 3 *The rationale behind each question*

Questions	Information required
1. What is the weight of semiconductors in total raw material costs?	Establishes a correlation between the importance of semiconductors and the weight of total raw material costs.
2. Rate the importance of this input in the final product's performance on a scale of 0 to 10?	
3. What kind of semiconductors do you buy?	Evaluates the semiconductor's complexity.
4. What were the main suppliers (Before the pandemic)?	Determines whether or not there was a change of suppliers in the period of analysis.
5. What are the main suppliers (At the present)?	
6. What were the buying prices? (Before the pandemic)	Determines whether or not there was a price change during the analysis period.
7. What is the buying price? (At the present)	
8. What is the process of selecting a supplier? Main steps and aspects to take into account	Details the different stages of a purchasing process.
9. What changes have you experienced during and after the pandemic?	Identifies the main market changes.
10. What are the most important drivers when choosing a supplier? (Before the pandemic)	Determines if there were changes in the main purchase drivers.
10.1 Rank in order of importance	
11. What are the most important drivers when choosing a supplier? (During the pandemic)	
11.1 Rank in order of importance	

12. What are the most important drivers when choosing a supplier? (At present)	
12.1 Rank in order of importance	
13. How has the pandemic and all the subsequent worldwide constraints changed the way these products are imported?	Identify the contingency plan implemented.
14. Is there any long-term plan established to avoid such constraints?	Determine the effects of the pandemic on the company's strategy.
15. What does the future hold for the semiconductor industry in the coming years, and how can Portuguese companies adapt to the increasing reliance on semiconductors?	Analyze the agents' future expectations for the industry.

3.2 Selection criteria and participants' profile

The first requirement was to select firms that integrate semiconductors on production lines in Aveiro District, Portugal. Following that, participant profiles were built based on their position in the purchasing process. They need to have a say in the ultimate decision-making process. This checking was done on the first contact through a phone call.

Regarding the type of industries, the aim was to integrate a diversified sample of industries in order to have a different point of view depending on how strategic semiconductors in these industries are. Telecommunication, Thermo technology, lighting solutions (automotive), power tools, and sensor solutions, among others, were some of the activities carried out by the participating firms.

We included additional criteria, such as the size of the company, because it would improve the study by introducing different perspectives. Furthermore, businesses from different sectors were targeted, as well as national and multinational company (based on Portugal, France, and Germany), and that involved decision-makers with extensive industry and company experience (as outlined in **Table 4**). These standards had to be met for a corporation to be considered eligible. Finally, the companies chosen were those that stated a willingness and availability to participate in this study.

All intervenients authorized the use of their names, as well as their position in the company. Just one element, Nuno Dias, who is the Segment Leader of Arrow Electronics, did not allow to indicate some clients' names. In this case, the companies' names were omitted.

Table 4

Information about the participants (name, firm, location, and position)

Name	Firm/Location	Current Position	Years of industry experience
Eduardo Dias (ED)	Bosch – Ovar	Supply Chain Manager	22
Manuel Arês (MA)	Aveiro University	Purchase Director of the Department of Electronics, Telecommunications, and Informatics	13
Ricardo Marçal (RM)	Altice Labs – Aveiro	Division Manager: Planning, Production, and Logistics	27
Nuno Dias (ND)	Arrow Electronics – Portugal Division	Technology Segment Leader IP&E EMEA	14
Rui Costa (RC)	Bresimar (works at the Bresimar brand – Tekon Electronics)	Production manager – Procurement and technical support	10

According to Richie & Lewis (2003), there are some requirements for the interviewer that, if not met, might compromise the outcomes. The first is the capacity to listen, think fast and logically, and have good recall. To meet these conditions, the interviews were recorded, a prior study of the company was done, and nearly no notes were taken during the interview to keep the focus on the conversation.

Furthermore, at the beginning of each interview, some explanations were given, such as the purpose of the study, the importance of the interviewed testimony, and the period in time that triggered the changes in the market - the pandemic - as a result the time period considered was “before” and “during the pandemic” and “at the present” are highly applied.

4. RESULTS PRESENTATION AND DISCUSSION

The initial inquiries aimed to understand the role of semiconductors in the total cost of materials as well as to discover the precise types of semiconductors that these businesses generally acquire.

The first observation was associated with the semiconductor segments. The interviewees distinguish two types of semiconductors: actives and passives. Active components include memories, processors, communication modules, and so on, whereas passive components include resistors, capacitors, inductors, transformers, and so on. Nuno D., who has extensive experience in supplying these components, claims that actives outnumber passives in the Portuguese market.

Table 5 depicts the relationships between the proportion of semiconductors in total material costs and the influence of semiconductors on end-product performance. The goal is to determine if the organizations place the same priority on these components since this could influence the subsequent responses.

Table 5

The weight of semiconductors in total costs of materials and the semiconductor's role in the final product performance (on a scale of 0 to 10)

	Weight of semiconductors in total costs	Importance in the final product performance (on a scale of 0 to 10)
RM	80%	8
ED	80%	8
MA	90%	9
RC	75%	10

Considering that, Ricardo M. and Eduardo D. refer that the costs of semiconductors represent 80% of the total costs, and as a result “are absolute strategic components on the performance of the final product” (RM).

Ricardo M. claims that before the pandemic, these expenses were lower than they are today (75%), attributable to "a supply chain shortfall, which contributed to an increase in prices."

Rui C., on the other hand, noticed that their considerable purchase of wires and electrical boxes accounted for the lack of correlation between the two questions in **Table 7**. Nonetheless, he agrees that semiconductors serve as the "brain" of the finished product.

Based on these two questions, it can be concluded that there is a relationship between the proportion of semiconductors in overall material costs and the importance of semiconductors in improving final product performance. All the interviewees unanimously acknowledge the crucial role these components play in the operation of their products.

Procurement evolution for suppliers

According to the literature, 80% of European countries buy through a distributor, as a result in this section, the analyze will focus on the procurement evolution for distributors rather than producers.

All of the interviewees agreed with the literature and confirmed that almost all transactions occur with distributors rather than producers. However, Ricardo M. added another viewpoint by stating that "significant negotiations take place between distributors and manufacturers," and highlighted that "certain manufacturers do not facilitate direct transactions; clients are required to engage with the distributor." Nevertheless, he pointed out that these transactions might potentially take place within the same negotiation context. He underlined that Altice and the manufacturer have a solid relationship, which facilitates conversations about the product's technical complexities.

After the pandemic, Ricardo M. mentioned that there was a slight switch in purchase behavior, companies are now more likely to buy directly from the producer.

Considering the aforementioned context, the question "Who are the main suppliers?" was formulated to identify the most important distributors in the Aveiro District companies. **Table 6** shows the frequency of each supplier's mention from the pre-pandemic period to the current time. The goal was to determine whether the pandemic had an impact on the supplier selection process.

Table 6

Main distributors before the pandemic and to the present

	Before	Present
Distributors	Number of mentions	Number of mentions

Arrow	III	III
EBV/ Avnet	III	III
Future	I	I
Luso Matrix	I	I
Rutronik	I	I
Digikey	I	I
Farnell	II	II
Mouser	II	II
RS	I	I
Texas (online distributor)	I	I
Wurth Elektronik (online distributor)	I	I
TME	I	I
Dash	I	I
Brokers/Dealers		III

Throughout the table, it can be concluded that there was general agreement that no significant changes in supplier selection were seen over this period. The only novelty is the arising of dealers/brokers during the pandemic until the present (which according to Rui C. and Ricardo M., “they always exist”).

According to Eduardo D., a dealer is an entity “that buys a stock where they could buy (from clients, suppliers, etc.) to sell at higher prices”. Ricardo M. explains that “clients who sold their stocks did so for two reasons: the prices to buy and sell are extremely high, and to get rid of obsolete semiconductors”.

Nuno D. added that in normal circumstances no one wants to work with dealers, because of the lack of quality guarantees. He also referees that “it’s similar to a black market”.

Three of the interviewees reached a consensus that these providers are no longer viable due to reasons previously mentioned by Nuno. On the other hand, Rui C. stated that they continue to buy from dealers but express a preference for procuring from official distributors.

In terms of purchasing channels, one that has grown with the rise of digitization is e-commerce. Rui C. emphasizes their professional collaboration with Digikey, Farnell, and Mouser, all of which operate online. He argues that “internet purchase is a more simplified

method that even allows negotiating with the distributor”. However, he points out one disadvantage which is “the non-competitive pricing and maximum purchasing quantities imposed by these websites”.

By contrast, at least two manufacturers, Texas, and Wurth Elektronik, are selling these components directly to end customers online. Rui C. notes that purchasing directly from producers typically results in lower prices. However, a frequent issue is the lack of available stock on their platforms.

Manual A. refers to buying some components through local distributors (TV Lar and Aveitrónica) but it’s “difficult to have good prices” and “They are structured to supply small clients”.

Prices evolution

According to the literature review and the insights obtained from the interviews, the pandemic had a major effect on all industries, resulting in supply chain disruptions and a large increase in prices.

During the pandemic, Ricardo M. indicates that some components went from costing 0,5€ to 50€. Eduardo Dias stated that “some components were 10 to 100 times more expensive than before”.

Additionally, Nuno D. stated that costs increased by 30 to 40% on average during that period. He provided the example of a client who initially purchased a component for 0.7€ but then began getting it through a broker for 7€ due to market shortages, resulting in a significant tenfold price increase.

Overall, Ricardo M. and Eduardo D. believe that prices are generally stable, with almost no substantial price discrepancies as they were. However, Manuel A. and Rui C. consider that prices are higher than they should be. According to Rui C., “The prices during the pandemic remain the same today but they are not increasing”. Manual A., on the other hand, notices a slight increase in the prices of some components. Despite these differences, all participants agree that prices are unlikely to return to pre-pandemic levels.

These two different perspectives could be related to the firm’s dimension and, as a result, to their bargaining power. Altice Labs and Bosch are two of the main references in electronic devices in the Aveiro district, so they have better conditions compared to the Aveiro University and Tekon - Bresimar.

This viewpoint was shared by Nuno D., who believes that pricing differentials are related to the volume of purchases rather than the size of the company. He claims that it is rational for companies like "Bosch and Altice" to negotiate more favorable terms compared to entities such as "Tekon - Bresimar and Aveiro University."

Procurement process

The table below shows how detailed is the procurement process of the companies interviewed. This level of detail can indicate the complexity of organizational structure that could impact the factors influencing an organization's purchase decisions.

Table 7

Purchase process

	ND	MA	RC	RM	ED
Supply audit (the certification and financial reports)			6°		1°
Presential visit					2°
Components identification (by development divisions)	1°	1°	1°	1°	4°
Producers' consultations				2°	5°
Distributer' Consultation	2°	2°	2°	3°	
Data Sheet Analysis			3°	4°	
Sample testing	3°		4°	5°	6°
Supplier approval			5°	6°	3°
Consultation/Negotiation	4°	3°	7°	7°	7°
Purchase	5°	4°	8°	8°	8°

Note: (ND) Nuno D., (MA) Manuel A., (RC) Rui Costa, (RM) Ricardo M., (ED) Eduardo D.

Bosch is the only firm that has centralized purchasing at the corporate level. Eduardo D. worked for a few years in the Purchase Department in Germany, which allowed him to talk comfortably about this centralized procedure at Bosch. However, some semiconductors are ordered straight from Ovar. In this case, Bosch Ovar conducts market consultations,

which begin at stage 4 (Identification of components by development divisions). Following that, they consult the Bosch Libraries (with all approved suppliers by the headquarters purchasing department) and proceed with the standard purchasing process.

As seen in **Table 7**, the stages of the purchase process differ among companies. Notably, Bosch Ovar and Altice Labs use a more extensive set of procedures during this process, resulting in a more complex method to select a supplier. Nuno D., a supplier of Altice Labs and Bosch Ovar, stated that these organizations are "more organized and more demanding," resulting in a more rigorous purchase procedure.

According to Nuno D., "Depending on the project a company is working on, the procurement process could take several months or even years before arriving at a purchase decision." He also mentioned that the duration of the process could be related to the level of organizational structure, adding that "Portuguese companies often exhibit less organization," which does not apply to Bosch and Altice. He emphasized that multinational firms had higher organizational efficiency and more solid procedures in general.

Additionally, Eduardo D. also introduced a technology used by Bosch to help them to make more accurate purchasing decisions. Total Cost of Ownership (TCO) provides purchasers with a thorough assessment of all associated costs, including lead times, transportation, supplier returns, and more. This is consistent with the viewpoint offered by Serrano et al. (2018), who argues that risk should be assessed by considering multiple factors at the same time, such as pricing, market instability, flexibility, and capital requirements. Considering this, it could be verified that Bosch and Altice Labs have an exhaustive purchase procedure, in contrast to Aveiro University and Tekon-Bresimar.

Justification for the market changes (during the pandemic up to today)

According to the interviewees, there were several changes caused by external factors that were related to the pandemic, geopolitical issues (conflict between the US and China), and more recently the war between Russia and Ukraine.

Table 8

The most mentioned market changes

Main changes	Number of mentions
New brokers/dealers	IV
The exponential increase in prices	V

Increased delivery times	V
Shortage of semiconductors	V

Table 8 shows the four indications that were mentioned by practically everyone and drove businesses to adjust their company management practices.

As mentioned before, the emergence of brokers was caused by a huge shortage of these components. Eduardo D. said that they just “wanted to buy wherever possible”, plus they asked headquarters to enlarge the purchase network. In this period, Ricardo M. added that they adopted a “survival management and not a strategic one as it is usual”.

As previously stated, the rise of brokers was caused by a severe scarcity of essential components. Eduardo D. stated that their strategy was just to "procure from wherever feasible,". Through the headquarters, they tried to expand their purchasing network. During this era, Ricardo M. explained that they used a "survival management approach rather than the usual strategic one."

As previously stated, buying through brokers implies some risks. Eduardo D. highlighted the "component falsification" issue that Bosch Ovar faced. Nuno D. added that chip counterfeiting was very common during this period.

Currently, Brokers maintain their business relationships with Bresimar. However, the other interviewees affirmed that brokers are not a viable option at the moment.

The other three changes—price increases, extended lead times, and semiconductor shortages—have been accompanied by explanations. Ricardo M. shared his perspective, stating that "60% of the chips imported from China were transported via commercial aircraft, which had to suspend operations during the pandemic." Additionally, some airlines transformed passenger planes into cargo planes. This put significant strain on both aircraft and container ships", which led to a general increase in prices.

Eduardo D. stated that "before the pandemic, lead times were approximately 40/50 days; during the pandemic, lead times escalated to 100, 200, or even 300 days." Currently, Rui C. admits the uncertainty regarding delivery times, stating that they “don’t how many days the delivery will take". He described one case in which they had to wait a year and a half for a delivery. He also mentioned that it is common to wait half a year for the packages. Manual A. shares the same difficulties and indicates that "they are waiting for a component (raspberry) since 2021."

Ricardo M. reveals that maritime transportation has been severely impacted. "There were many difficulties in shipping packages from China to Europe due to a lack of containers, the Chinese government forced companies to ship only 100kg of material per day and per factory." He explains that "normally, containers arriving from China are refilled and sent back to China; however, the time to fill a container ship was too long during this period, and as a result, many maritime companies had to send empty containers back China." This procedure resulted in increased container pricing and longer lead times, which were reflected in the final product price.

Eduardo D. explains that as a result of these constraints, the cost of a 40-foot container, which was initially approximately six to seven thousand before the pandemic, increased to a range of \$20 to \$30 thousand during the pandemic. As a result of this new scenario, Bosch was forced to rely on air transportation, "which resulted in a substantial increase in prices". Ricardo M. states that the cost of maritime transportation increased by 3000%.

Regarding these drawbacks, Manuel A. claims that there has been an increase in demand for electronic devices, which has aggravated the semiconductor shortages and contributed to unusually extended delivery times.

Aside from that, Manuel A. stated that certain events that occurred before and after the pandemic are having a significant impact on market uncertainty. Such events include the Russia War, tensions between China and Taiwan, and US sanctions against China.

Manuel A. expresses serious concerns about recent geopolitical events. He believes that "political activities are killing globalization, in the sense that this industry lives primarily because of producer collaboration, and, as a result, technological progress could be affected in the coming years, particularly in the memory and microcontrollers segment."

The majority of the components, according to Manuel A. and Ricardo M., are from China. According to Manuel A., during the pandemic, "Chinese government took extreme measures to contain the virus, closing entire cities, affecting the entire value chain, resulting in higher lead times."

In summary, some concerns have significantly influenced the procurement strategies of companies for these goods. The cost of maritime transportation was highlighted most frequently by both Ricardo M. and Eduardo D., followed by the influence of aviation transportation. This was frequently associated with the geographic location of the suppliers

- Asia, and European distributors. Other interviewees agreed that these factors had a significant impact on their value chains, even when working with European distributors.

Ricardo M. and Eduardo D. believe that factors such as lead times, prices, and semiconductor shortages have reached a relatively more stable state, yet they remain distant from the pre-pandemic levels. However, Manual A. and Rui C. do not see any major changes since the pandemic's peak.

As mentioned before, Nuno D. explained these different opinions, stating that “distributors offer more favorable conditions to clients who make larger purchases, such as Bosch and Altice”.

Evolution of the purchase drivers of semiconductors

Table 9 shows the number of mentions of a purchase driver in three separate periods: before the pandemic, during the pandemic and at present. It provides us with an evolutionary perspective on how purchase drivers change over time. The current literature (point 2.5 of the literature review) as well as the interviews, were used to identify the purchase drivers.

Table 9

Evolution of the purchase drivers

Purchase Drivers	Number of mentions		
	Before	During	Present
Quality	III	III	III
Price	IIII	IIII	IIII
Technical assistance	II	I	I
Agile communication	IIII	III	IIII
Stock availability	III	IIII	III
Payment conditions	I	I	I
Financial strength	I	I	I
Lead time	III	III	III
Cultural aspects			I
Official distributor	I	I	I

Price, quality, and lead time were frequently considered the most important drivers, and their importance remained constant across all three periods. These factors constitute the foundational elements that underpin the decision-making process for the interviewees.

Another unanimously mentioned evidence was the importance of agile communication with suppliers. However, Eduardo D. recognized that during the pandemic, their focus was shifted to responsibilities such as seeking new suppliers, which intentionally resulted in a breakdown in communication with existing ones.

During the pandemic, multiple events resulted in a semiconductor shortage, which was reflected in purchase drivers. Stock availability was a major worry for everyone interviewed. At present, only one of them believes that is no longer a driver for purchasing decisions.

As the literature suggests, Eduardo D. identifies cultural issues as one of the current purchase motivations. He stated that they are looking for the Asian market differently because "the Asian market is a very specific and unreliable market." In addition, he shares an incident in which a "supplier did not deliver a specific good because the Chinese government implemented measures to reduce energy consumption and they closed entire facilities just because of one Covid-19 case."

As a result, Eduardo D. "introduced a risk factor on the TCO for all components from Chinese suppliers, that was one of the biggest changes that we implemented,". He also stated that there was no significant change in the drivers that lead the procurement departments.

The additional factors that were mentioned and did not change over time were financial strength, which is linked to supply guarantees (noted by Eduardo D.), appropriate payment terms, and official distributors, which means that dealers are not an option.

Table 10 presents the main findings of the study's investigation. In this question, respondents were asked to rank the purchase drivers across the three time periods. The goal was to determine the evolution of their purchasing priorities over time. The analysis was divided into two subsections. The first subsection focused on the evolution of the purchase drivers from the period before the pandemic until the present time. The second subsection analyzes the purchase drivers during the pandemic.

Table 10

The evolution of the purchase drivers' priorities

Rui C.	Before	During	Present
Stock availability	1°	1°	1°
Price	2°	2°	2°
Lead time	3°	3°	3°
Official distributor	4°	4°	4°
Payment conditions	5°	5°	5°
Agile communication	6°	6°	6°
Eduardo D.			
Quality	1°	2°	1°
Financial strength	2°		3°
Lead time	3°	3°	5°
Stock availability	4°	1°	4°
Price	5°	4°	2°
Technical assistance	6°		
Agile communication	7°		6°
Culture issues			7°
Ricardo M.			
Quality	1°	3°	2°
Technical assistance	2°	4°	1°
Agile communication	3°	5°	3°
Stock availability	4°	1°	4°
Price	5°	2°	5°
Manuel A.			
Price	1°	2°	1°
Lead time	2°	3°	2°
Agile communication	3°	4°	3°
Quality	4°	5°	4°
Stock availability		1°	

The preliminary data reveals that three companies showed deviations in purchasing habits both before and during the pandemic. Altice Labs, Aveiro University, and Bosch Ovar

were some of the companies that adjusted their purchase drivers. Rui C., the only interviewee who did not modify their patterns, stated, "There was no change in these three periods."

Manuel A. argues that during the pandemic, they felt obligated to change their purchasing patterns by prioritizing the stock availability of their suppliers rather than the price. Despite what he previously stated about the 2021 delay order, stock availability is no longer critical because there are more supplying alternatives in the market.

Before the Pandemic to the present

When comparing the first period (before the pandemic) with the last period (present) it can be concluded that the only two companies that are changing their purchase criteria are Bosch and Altice, which means that they had effectively changed their buying patterns.

Ricardo M. states that before the pandemic, quality was the number one priority followed by technical assistance. Currently, he explains that the active engagement of suppliers (technical assistance) in their business operations holds substantial value, and this factor has risen to become the top criterion for Altice Labs.

On the other hand, Eduardo D. still considers product quality the number one priority for the company. The first change was the price, today Bosch is considering the price as the second priority, and when comparing it to before the pandemic period, it was proved that the price was in fifth place, which suggests that the price is higher than before the pandemic, as it was previously stated. This viewpoint contrasts with the perspectives shared by Rui C. and Manuel A., who consistently regard price as one of the top two priorities across all three analyzed periods. This could be related to the company size, Bosch and Altice Labs have different dimensions and as a result different purchase volumes. Nuno D. indicates that companies with more purchase volumes tend to have better commercial conditions. Besides that, Eduardo D. states that they work in the automobile sector which is "one of the most demanding sectors" which leads to non-price prioritization and focus on other drivers which are equally important.

Another mentioned aspect was the supplier's financial strength. Eduardo D. was the only interviewee who mentioned this criterion and justified it by stating, "It is an important factor that provides us with assurances of sustained supply in the medium to long term."

During the pandemic

As mentioned before there was a semiconductor shortage that forced firms to turn to “black market or dealers”. With regard to this matter (supplying urgency), all the interviewees considered stock availability the most important criterion during the pandemic. Plus, price was the second most important factor for 3 interviews.

During the pandemic, it was notorious that all the interviewees considered the price, stock availability, lead times, and quality as the top 4 priorities. Despite other criteria that they selected these were the most important drivers for the purchase departments. As Ricardo M. stated they were in a “survival position and not in a strategic one”.

To conclude, there have been changes in half of the companies such as Bosch Ovar and Altice Labs. Manuel A. and Rui C. will proceed with the same criteria that they had before the pandemic.

Business adaptation to market constraints

Table 11

Number of mentions of implemented measures

Implemented Measures	Number of mentions
Extended planning	V
Local to local	IV
Increase safety stocks	II
More supply options	II
Reduction of the number of components	II

The prevailing conclusion in this section is that businesses have diverged from their regular operations. According to all interviews, the pandemic forced them to expand their planning processes and engage with extended forecasts. Ricardo M. explains that "currently, suppliers are unable to ensure supply within short timeframes."

Rui C. states that “Tekon plan their needs half a year ahead, which is a lot compared to what we previously did”. Ricardo M. added they were “obliged to extend the delivery times to our clients, as a result, we decided to do long-term forecast until 70 weeks”, “Today we are finishing 2021 orders and doing new production orders for 2024, this extended planning is something that came with the pandemic, and we pretend to maintain”. Additionally,

Manuel A., affirms that they are “making a 1-year forecast of future material needs from suppliers”.

In addition, local-to-local is a measure that has even more preponderance within the business. 4 out of 5 respondents consider that after the pandemic they start to prefer to buy from local suppliers and by local suppliers they mean European producers. Nuno D. states that “there is a more sensibilization for made-in-Europe components”, however, Manuel A. believes that "we do not have enough European production to meet our demanding market, and all the factories that are being established in Europe will take a long time to start producing". Considering that European components have a higher price compared to Asian components, it is notorious that it will take some time until Portuguese companies start to put together these two criteria (competitive prices and made-in-Europe products).

Regarding the increase of safety stocks, Nuno D. believes that it is something that is changing in the industry, the “company’s trend is to work with the lowest stock as possible, although important players are going in an opposite direction and are increasing their safety stocks to avoid shortcuts”.

Eduardo D. and Manuel A. both mentioned supplier diversity, implying that searching out new sources could reduce reliance on specific suppliers and components. Eduardo D. went further and underlined the importance of “having several component and supplier options for the same product”.

Ricardo M. emphasized the "extreme importance of reducing dependency on certain suppliers." He highlighted the importance of having versatile products that can effectively fit a wide range of components. Nuno D. stated that reducing the number of purchased components would aid in reducing stockouts.

To reduce this dependency, it is important to have a printed circuit board (PCB) with a dual footprint, which means electronic boards with the possibility to work with different components, which allows to reduce the component dependency as well as the supplier. In the next section, Ricardo M. will elaborate on the strategic significance of this approach for Altice Labs.

Strategic plans

It was already noted that companies are adjusting their purchasing strategies. However, it is critical to determine if there is a strategic plan for the medium and long term to reduce the dependency on specific components and suppliers.

Ricardo M. highlights that Altice Labs detain their development department, a unit that has been expanding post-pandemic. The goal of this department is to conduct product validations and create new versions of electronic devices using electronic reversions while maintaining the products' electronic performance. Making investments in this developmental component, according to Ricardo M., is critical to reduce reliance. He adds that this is the path to which Altice Labs is fully committed.

As outlined in the literature review, Eduardo D. stated that "Bosch is engaged in a strategic investment," referring to a project that began before the pandemic and involves the development of a semiconductor factory in Germany. He went on to say that the key goal in the early stages is to appeal to various Bosch segments. This strategic shift suggests that Bosch is pursuing a vertical integration approach.

On the other hand, Rui C. and Manuel A. respond that there isn't any plan to avoid this dependency.

In conclusion, it is notorious that firms that have higher financial capacities are more proactive in preparing for new market constraints. Eduardo D. pointed to the cyclical nature of such crises, suggesting that "they might be caused by a single incident in one region of the world, such as the earthquake in Japan, which interrupted the entire supply value chain. As a result, being ready for the next unexpected incident is critical".

The industry's future

In terms of agents' opinions about the future of the industry there was almost a consensus about the urgency to bring semiconductor production to Europe and governments have an important role in ensuring that this will happen. Eduardo D. added that "it is urgent to reduce Chinese semiconductors". On the other hand, Ricardo M. believes that "the way is not to bring the production to Europe, we are not a country of manufacturers, and neither is Europe", he states that "the industry's future is the investment in product development". Manuel A. states that production "should not leave Europe", and governments should bring it again to the Western countries". This opinion was also shared by Nuno D. who believes "governments will increase the customs duties for Chinese semiconductors and will allocate more funds to this industry"

In the short-medium term, Nuno D. also believes that there “will be a dislocation of Chinese suppliers to Vietnam due to the US sanctions to Chinese companies” “which is already notorious with the huge investments that are being made in this region.”

5. CONCLUSIONS

5.1 General Conclusions

The goal of this study was to determine if the external events caused by the pandemic at the beginning of 2020 changed the way that electronic companies in the Aveiro District purchased semiconductors, specifically to determine if the purchase drivers of these components changed. This research lead to the conclusion that purchasing trends in this region have in fact changed.

The analysis of the global semiconductor industry concluded that it has a great growth potential, around 66.2% by 2030. Besides that, the Portuguese trade balance verified a significant imbalance which makes Portugal extremely dependent on foreign suppliers, specifically Asian.

A further section addressed some indicators that may have an impact on organizations' operations. Due to the rigorous requirements to begin production, there are just a few manufacturers. Aside from that, the industry is distinguished by the great specialization of the value chain. Almost any corporation runs all stages of production. The only firm in Taiwan that provides more complete solutions is TSMC, which is an absolute strategic corporation for the entire industry. As a result of these factors, this market is heavily reliant on a few producers, which implies that a single disruption in a single location could compromise the entire value chain.

The preliminary results of the interviews indicated that there were no substantial changes in the key distributors; companies are still being supplied by the same agents as before. The only difference is the addition of brokers as an alternative. Currently, only one respondent confirms that they are consulting brokers.

The appearance of brokers, alongside with exponential increase in prices, delivery times, and shortage of semiconductors were the main market changes identified during the pandemic. Recently, all interviewees considered that these elements are more stable, but they are still causing some constraints.

Considering the above-mentioned market description, it was possible to conclude that there was no significant introduction of new purchase drivers. Price, product quality, lead time, agile communication with suppliers, and stock availability were the most often highlighted drivers before and during the pandemic, and they continue to be the same now.

Nowadays, stock availability is becoming the least important driver. The only novelty driver mentioned by one interviewee was the cultural issues related to the Chinese regime.

On the other hand, there have been significant changes in the evolution of the purchasing drivers' priorities at this stage, particularly among the multinational businesses' interviewees. Technical assistance and price were the indicators that obtained more importance following this period. Quality and pricing were the features with more mentions in the post-pandemic period. Another trend is the increased emphasis of the safety stocks. This observation is consistent with the data presented in the Literature Review section.

It was also possible to observe that only two companies are adopting new strategies to reduce their vulnerabilities to the external market, and the other two consider that they could do nothing to reduce this dependency on the Asian market.

The literature review and the interviews showed that this market is in a profound change. Companies and governments are more concerned about geopolitical issues that may affect semiconductor industry. Companies are more aware of these changes and part of them are implementing new strategies to avoid dependency on the Asian market.

5.2 Limitations and suggestions for further research

The key constraint of the study was the difficulty in precisely characterizing the population. Numerous electronics businesses operate in the Aveiro district, although not all of them are active in electronic device assembly, resulting in a group that does not purchase these components. As a result of this circumstance, the sample size for the study was quite limited.

Moreover, the sample consisted of individuals who play a role in the purchasing decision-making process. Nevertheless, there was no differentiation made regarding the profiles of those who were interviewed. As a consequence, there were interviews conducted with individuals possessing more technical backgrounds as well as others with stronger management skills. This situation could potentially impact the integrity of the outcomes different buyer profiles may have different purchasing behaviors.

Another limitation identified throughout the inquiry was the disparity in operational approaches based on the company's market positioning as well as the firm's dimension. For

example, multinational firms such as Bosch Ovar and Altice Labs have certain similarities in terms of bargaining strength and the execution of rigorous processes. In contrast, the comparison with companies such as Bresimar and Aveiro University reveals a significant change in the elements that drive decision-making. That is the reason why Nuno D.'s interview was so important to help respond to the thesis objective. He gave a broader sense of how the industry operates and how the decision-makers behave in this process according to the firm's features.

Considering how dynamic this industry is, and the transformation that is taking place, it's pertinent to enlarge this study to the rest of Portuguese enterprises – purchasers of semiconductors – and distinguish firms according to their influence by foreign companies, such as multinationals or even Portuguese companies that worked exclusively for the automobile sector – which according to Eduardo D. is one of the most demanding industries in the world.

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