DEPARTAMENT OF
MECHANICAL AND INDUSTRIAL ENGINEERING

SORAYA NATÁLIA SAWANGA DIAS
Licenciada em Ciências de Engenharia e Gestão Industrial

A PORTER'S FIVE FORCES MODEL PROPOSAL FOR ADDITIVE MANUFACTURING TECHNOLOGY: A CASE STUDY IN PORTUGUESE INDUSTRY

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ABSTRACT

Industry 4.0 constituted a trigger to a new phase in the Industrial Revolution, heavily focused on the interconnectivity of the systems, bringing disruptive technologies such as Additive Manufacturing (AM). On top of that, the shift from an industrial economy to a knowledge-based economy, where knowledge is the actual raw material, implies changes in the labor market, as new jobs strongly rely on knowledge-intensive activities. This forces organizations to rethink their way of operating, since markets are getting even more competitive and susceptible to greater volatility. Herewith organizations, are resorting to AM to strengthen their competitive position, as this technology allows them to seize new opportunities. As a response to that, this dissertation presents an industry analysis to AM based on Porter's Five Forces model, where forces such as the threat of new entrants, bargaining power of customers, the threat of substitutes, bargaining power of suppliers and rivalry among the existent competitors will be discussed under a knowledge perspective. To validate the proposed model's practical applicability, a case study was conducted based on a questionnaire that was applied to organizations operating with AM in Portugal. The information collected on the questionnaire supplied the forces of the proposed model. After the analysis was possible to conclude that all the participating firms, except one, fit in the incremental stream of development as regards to Additive Manufacturing technology: Closed-incremental stream, in this stream AM technologies appear as a complementing tool. Regarding the case study results, the participating firms seem to experience the low capability to capture specialized workforce for AM, high capital requirements to enter the market and low IPR regulation. AM brings an opportunity for higher bargaining power to arise due to 'prosumerism', yet it does not add value as a tool for the standard products industry. Moreover, suppliers strongly influence sectors' competition, which will presumably suffer from increased rivalry tensions. For future development, the study of the developed model in a corporate environment where the adoption of the Additive Manufacturing technology is at a more advanced level is suggested.

Keywords: Additive Manufacturing; Porter's Five Forces Model; Industry 4.0; Knowledge Economy.

Resumo

O despoletar da Indústria 4.0 desencadeou uma nova fase da Revolução Industrial, fortemente ligada à interconectividade dos sistemas, fomentado o aparecimento de tecnologias de carácter disruptivo como o Fabrico Aditivo (FA). Para além disso, a transição de uma economia material para uma economia baseada no conhecimento, onde o conhecimento é a matéria-prima, tem implicado mudanças ao nível dos mercados de trabalho, onde as novas tarefas dependem agora de atividades intensivas de conhecimento. Uma vez que os mercados estão cada vez mais competitivos e suscetíveis a grande volatilidade, as organizações têm sido forçadas a repensar o seu modo de operar. Para isso têm recorrido ao FA, que se apresenta como um meio para reforçar a sua posição competitiva e aproveitar novas oportunidades. Por forma a responder a este problema, esta dissertação apresenta uma análise da indústria, segundo uma perspetiva de conhecimento, aplicada ao FA baseada no Modelo das Cinco Forças de Porter, onde as forças analisadas são a ameaça de novos entrantes, poder de negociação dos clientes, ameaça de substitutos, poder de negociação dos fornecedores e rivalidade entre os concorrentes. Para validação do modelo proposto, foi realizado um estudo de caso através da aplicação de um questionário a empresas que operam com o FA em Portugal. Depois da análise efetuada a essa informação foi possível concluir que todas as empresas que participaram do estudo, exceto uma, se encontram numa fase incremental da adoção da tecnologia de FA, onde as tecnologias de FA surgem como ferramentas complementares à produção. Em relação ao estudo de caso, as empresas participantes experienciam dificuldades em recrutar trabalhadores qualificados na área do FA, elevados investimentos para entrar no mercado e baixo controlo quanto a direitos de Propriedade Intelectual. O FA proporciona o aumento do poder de negociação dos clientes, como consequência do 'prosumerismo', no entanto não acrescenta valor como ferramenta para a produção de produtos standard. Os fornecedores detêm grande influência sobre os setores, que presumivelmente sofrerão de elevadas tensões de rivalidade. Como proposta de trabalho futuro sugere-se a extensão deste estudo a um ambiente corporativo, onde a situação de adoção do FA esteja mais avançada.

Palavras-chave: Fabrico Aditivo; Modelos das Cincos Forças de Porter; Indústria 4.0; Economia do Conhecimento.

CONTENTS

LIST OF FIGURES

List of Tables

ACRONYMS

AM	Additive Manufacturing
AI	Artificial Intelligence
AR	Augmented Reality
CAD	Computer Aided Design
CPS	Cyber-Physical Systems
DIKW	Data-Information-Knowledge-Wisdom
DMS	Distributed Manufacturing Systems
EPR	Extended Producer Responsibility
EUR	Extended User Responsibility
FDM	Fused Deposition Modeling
GRA	Grey Relation Analysis
ICT	Information and Communication Technologies
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
KM	Knowledge Management
KMS	Knowledge Management Systems
KM3D	Knowledge Management in Additive Manufacturing
LMD	Laser Metal Deposition

LOM	Laminated Object Manufacturing
OEMs	Original Equipment Manufacturers
PSS	Product Service Systems
P2P	Peer-to-Peer
RP	Rapid Prototyping
SCs	Supply Chains
SCF	Supply Chain Flexibility
SCP	Supply Chain Performance
SECI	Socialization-Externalization-Combination-Internalization
SLA	Stereolithography
SLS	Selective Laser Sintering
SMEs	Small and Medium-Sized Enterprises
3DP	Three-Dimensional Printing

1

Introduction

The present dissertation for obtaining the degree of MSc on Industrial Engineering and Management at NOVA School of Science and Technology from NOVA University of Lisbon was carried out within the scope of the research project "Knowledge Management in Additive Manufacturing (KM3D)". This introductory chapter presents the scope and motivation, the objectives to be achieved, the methodology followed and a description of the document structure.

1.1 Scope and Motivation

The constant technological evolution that the world has been witnessing in the past few decades is imposing a high pace at the global markets (Gwangwava et al., 2018). New disruptive technologies are creating room for novel types of production to appear, enabling new approaches to businesses and at the same time, emerging to respond to the ongoing digital transformation that calls for high levels of efficiency and flexibility (Bogers et al., 2016; Huang et al., 2013). Consequently, customers are getting more demanding and gaining access to a diversified range of offers, leading to greater market competitiveness and volatility. This volatility stems from the fact that customers start to possess substantial bargaining power over suppliers given that, with the growth of e-commerce, they have the freedom and access to information which allows them to choose who to buy from based on their own criteria (Dälken, 2014). Therefore, organizations need to be dynamic and always looking for ways to strengthen their market position and, consequently, achieve advantage over their competitors (Ramezan, 2011).

As globalization and disruptive technologies continue to gain force, the context adjacent to industries is becoming very distinct from the one Porter (Porter, 1979) studied and from which he built his five forces model. At that time, the logic was based on choosing a strategy that allowed the organization to create a privileged position against the competition, e.g., by exploiting economies of scale (Porter, 1979). Currently, the focus is shifting towards an industry where the combination of technology with knowledge allows organizations to achieve that privileged position and where the actual raw material of organizations is knowledge. Although Additive Manufacturing (AM) is still maturing as a direct way of manufacturing, a lot of speculation has been made around the new opportunities that this technology brings to the table (European Commission et al., 2016; Godina et al., 2020).

As a fast-developing field, where existing technologies are being considerably improved and new processes created, the decision-making process when working with AM can be complex due to its disruptive character (Eddy et al., 2016). One reason for that is that AM knowledge can be vast and complex (Godina et al., 2019).

At this stage AM still divides authors regarding the impact that its adoption will bring to business models. As this topic is an emerging area of research, where tangible or case-based evidence are still scarce, knowledge and assessment models are crucial (Godina et al., 2020; Savolainen & Collan, 2020). To contribute to cover this gap, this dissertation starts by summarizing some fundamental concepts of AM business models, contemplating knowledge economy. Then, to understand the role that this technology will take in this digital era, this study presents an industry structural analysis, based on an adaptation of Porter's five forces model (Porter, 1979), for emerging business models in the field of additive manufacturing. The analysis is performed under a knowledge perspective, since knowledge is one of the most critical assets nowadays, as it is through the proper exploitation and application of it – together with these new technologies, namely AM – that organizations will be able to achieve competitive advantage over their rivals (Nonaka, 1994).

1.2 Objectives

As the current business environment is increasingly dynamic, and where numerous technological innovations appear, the know-how produced is of great importance, yet volatile as markets change quickly. Thus, knowledge and how it is shared and engaged in organizations have become a source of competitive advantage. Consequently, it is necessary to develop approaches that assist organizations in managing their knowledge and supporting it for value creation. In the case of AM, knowledge management processes are even more critical because this is a disruptive and emerging industry with innovative and complex products, where business models' dynamic is not yet known. Despite the opportunities this technology promises to bring, the doubts concerning its future developments and impacts remain.

As such, the present study explores how AM adoption gives rise to new business models, focusing on how it impacts the firms' business strategy.

The aim of this dissertation is then to create a Porter's Five Forces model (Porter, 1979) for emerging business models in the field of AM. To this end, the objectives to be achieved are:

- Study the impact of AM in organizations' business strategy
- Study AM adoption levels within Portuguese firms

To accomplish this, the following activities were defined:

1) Adaptation of Porter's Industry Structural Analysis model (1979) to AM technology industry.
2) Test the adapted model on the industrial fabric using AM technology in Portugal.
3) Strategic characterization of the organizations using AM technology in Portugal.

1.3 Adopted Methodology

This section describes the development phases for carrying out the present dissertation. This study was conducted in seven phases, as shown in Figure 1.1:

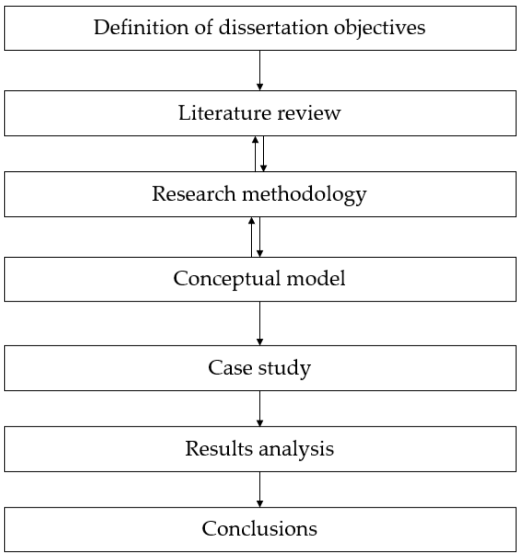

Figure 1.1- Phases of the adopted methodology

After defining the dissertation objectives, specified in the previous section, a literature review is conducted to gather information regarding the theoretical background of the study such as AM technology, emergent business models in the field of AM, knowledge economy and knowledge management. The procedure to develop this phase can be seen in detail on Chapter 2.

The research problem in study consists in the impacts AM have on firms' business strategy, and consequently on the competitiveness of the sectors using this technology. Accordingly, two research questions arise:

- How does AM technology impact firms' business strategy?
- How are the levels of AM adoption within Portuguese firms?
- How does knowledge management help streamline the use of AM technologies?

To answer these questions, the Research methodology chosen follows a deductive method with an interpretive philosophical stance. A deductive strategy entails moving from general to particular (Woiceshyn & Daellenbach, 2018), where the aim is to reach conclusions by making logic assumptions of two or more premises asserted to be true. Therefore, the deductive research process starts with theoretical argumentation and then tests arguments with empirical observations (Järvensivu & Törnroos, 2010). On the other hand, a philosophical stance, also known as philosophical paradigm, is the "set of beliefs that guides action" (Guba & Lincoln, 1994). As for the interpretive paradigm, the aim is to achieve deep understanding of the social phenomenon under study. Thus, the choice of this paradigm is justified by the fact that one goal of this study is to understand the interaction between social changes and technological advances (Memmi, 2014) – in this case, by Additive Manufacturing on organizations. Another reason to choose this perspective is that the interpretive stance recognizes the importance of participant's subjectivity as part of this process, which will be a fundamental key for this research validation (Rashid et al., 2019).

The theoretical argumentation in this work derives from the literature review (Chapter 2) culminating in the conceptual model presented in Chapter 3. Then, these arguments are validated with empirical observation through an exploratory case study. According to Yin, 2003 a case study is a research strategy that allows to understand a phenomenon in real life situations. The decision to conduct an exploratory case study research, qualitative in nature, is based on three reasons. Firstly, the nature of the problem under investigation requires an in-depth exploration of the phenomena (Rashid et al., 2019), since it encompasses a disruptive technology and its impact on organizational structures. Secondly, a case study not only allows to observe, explain and explore a phenomena, but it also provides a methodical way to look at events, collecting data, analyzing evidence and report the results (Verner & Abdullah, 2012). As such, this is a reasonable method to assess the impact of AM technology on firms' business strategy by looking at a reduced dataset. Lastly, as this work focuses on contemporary events, where the investigator has no control over behavioral events, and intents to understand the participant's thoughts regarding the impact of AM on their organization (Yin, 2003).

Then, after defining which factors influence organizations' environment was followed the construction of a conceptual model applied to AM based on Porter's Five Forces model (Porter, 1979). This model can be seen in detail on Chapter 3 as well as the evidence that allowed the formalization of the research questions in hypotheses. For validating the practical applicability of this model is conducted case study research through an online questionnaire to Portuguese firms using AM. For this process, the statements that originated the research hypotheses were included on the questionnaire, to corroborate, or not, the veracity of the facts presented in the tentative theory (proposed model). To accomplish the case study are applied quantitative methods to primary data, from the questionnaire, and secondary data. The secondary data used is existing data from a previous survey carried out within the scope of the research project. The methods used for collecting and analyze the gathered data are explained on Chapter 3. Chapter 4 introduces the case study and presents the results, and respective discussion.

Lastly conclusions are drawn regarding the importance of this study, if the proposed objectives are achieved and the evidences of the conducted analysis. In this section are also reclaimed the expected contributions with this research as well as suggestions for future work.

1.4 Dissertation Structure

The document is divided in five chapters as schematized in Figure 1.2:

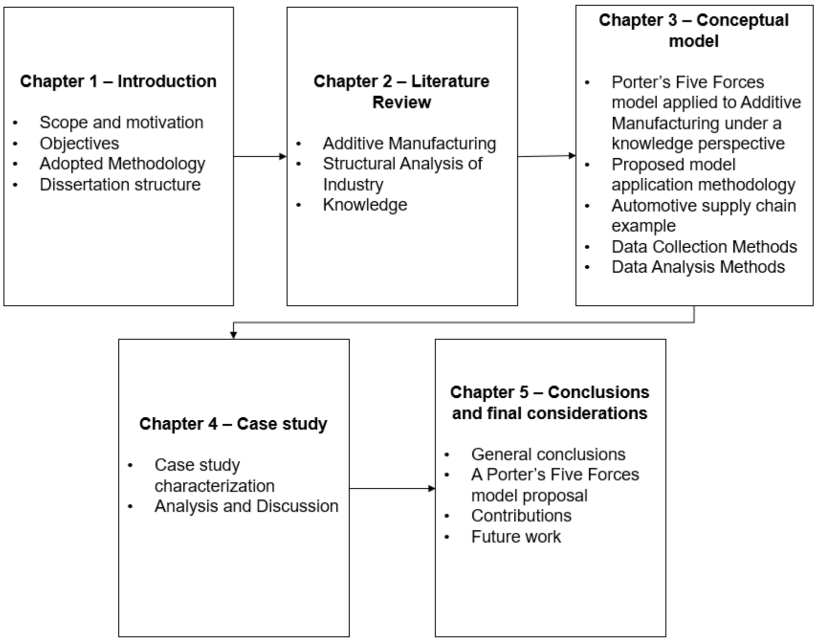

Figure 1.2- Document structure

1) Introduction

The first chapter serves the purpose of explaining the scope and motivation behind this study, as well as introducing the objectives to be reached with this dissertation. The adopted research methodology used to conduct this study and the dissertation structure also make part of this chapter. As for the research methodology, are stated and explained the phases required to conduct the study, discussed the research problem and the research design, which consists of a case study.

2) Literature review

The second chapter comprises the theoretical fundamentals of the study. Here are examined crucial subjects for the understanding of this dissertation such as: Additive Manufacturing technology, Structural analysis of the industry by Michael Porter (Porter, 1979), Knowledge economy and Knowledge management. These subjects are, in turn, broken down into several concepts like AM processes, AM and other technologies of industry 4.0, AM applications, AM impacts and barriers, emergent business models for AM technology, Porter's Five Forces model (Porter, 1979), knowledge generation and knowledge management processes.

3) Conceptual Model

The third chapter proposes a model connecting Porter's Five Forces model (Porter, 1979) and Additive Manufacturing, in light of knowledge economy. The construction of this model arises as an exercise accomplished by evidences found on the literature review relating to AM and Porter's Five Forces model. In the end of the chapter, a method for operationalization of the model is presented, along with the data collection and data analysis methods. It is this phase that allows the development of a questionnaire to assess the veracity and applicability of the proposed model.

4) Case study

This chapter explains the case study. It starts by describing the process of firms' selection and characterizing the participating firms. Then, it is presented the analysis of the results obtained with the online questionnaire. For this, first is made a description about firms' respondents from the sample, followed by a characterization of the industrial fabrics using AM technology in Portugal. After, a data analysis is conducted to confirm the veracity of the proposed model. This analysis is divided into two main parts which are a general analysis of the responses and then a grouped analysis, where the participating firms are combined according to the economic sector of activity so that differences, or similarities, between the sectors can be compared.

5) Conclusions and final considerations

Lasty, this chapter presents the conclusions regarding the study conducted, the limitations and contributions that are expected with this work as well as suggestions for future work development in the area of Additive Manufacturing business models and strategy.

2

LITERATURE REVIEW

As this dissertation output is an industry analysis of emerging business in Additive Manufacturing from a knowledge perspective, it is important to contextualize not only industry 4.0, as driver of AM, but also the theoretical groundwork behind this analysis as well as a description of the changes that knowledge economy brought. Before delving into that, this introduction will provide a section describing the adopted methodology to conduct the literature review to meet the objectives outlined for this study.

2.1 Literature Review Methodology

A literature review acts to summarize actual knowledge related to a specific topic (Snyder, 2019). In this case, this dissertation condense information regarding AM, the impact it has on firms' business strategy– and consequently on business models – as well on organizations' knowledge management practices and Porter's Five Forces model (Porter, 1979). The structuring of this literature review was carried out in five phases, which were:

1) Definition of the topics to address;
2) Search for articles and documents in accordance with the chosen topics, through keywords like "Additive Manufacturing", "Industry 4.0", "Business Model", "Porter’s Five Forces model" and "Knowledge economy" in indexing databases, such as Web of Science and Scopus;
3) Articles/ documents selection;
4) Summary of the collected information;
5) Structuring of the literature review.

The article selection was conducted based on the explanations of Professor Srinivasan Keshav on "How to read a paper" (Keshav, 2007). After defining the main aspects and the search for articles, this methodology helps understanding which information is relevant based on a three-pass approach. The first pass is a quick scan to understand what type of paper is, context and what are the contributions. This is achieved by reading the title, abstract, introduction, section and sub-section headings and conclusions. In the second pass the intention is to read with greater care, by looking at figures, diagrams and graphs, among other illustrations. It is also important to look at references in order to learn more about the background of the article (and consequently on the topic). The third pass requires greater attention to detail and at the end the reader must be able to identify strong and weak points as well as point to potential issues (Keshav, 2007). Figure 2.1 summarizes the approach followed to structure the literature review.

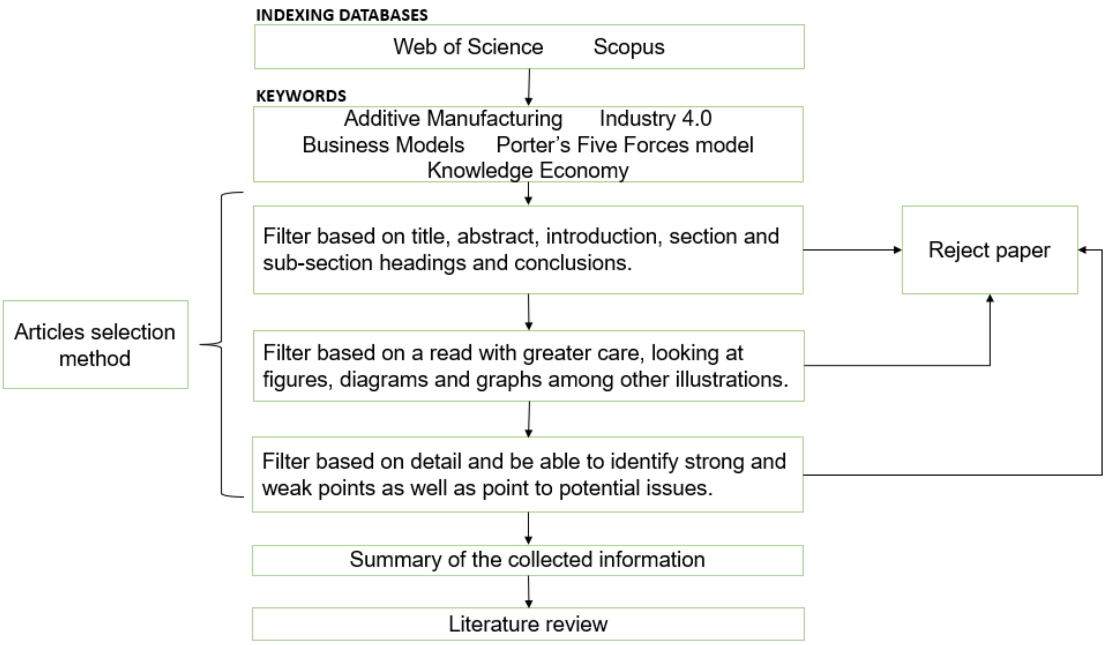

Figure 2.1- Literature review methodology (Adapted from Botelho et al., 2021)

The literature review was supported by scientific articles, book chapters, company study reports and academic works, including master's dissertations. This research was carried out between March and June of 2021. In total, 207 documents of the types described above were considered. Of these 207, 73 were excluded, resulting this literature review from the remaining 134. In some cases, the snowball technique was used, by tracking references from key documents. It is also important to mention that there are some articles whose publication date is more recent than the search timeline. This occurred as after conducting the search it was still necessary to extend information in a few topics.

2.2 Additive Manufacturing

2.2.1 Industry 4.0 as Propulsor of Additive Manufacturing

The Industry 4.0, also known as Fourth Industrial Revolution, has been a turning point to a new era in manufacturing, leading to digitalization of business models, environments, production systems and machines, among others (Alcácer & Cruz-Machado, 2019). In other words, Industry 4.0 is "the technological transformation towards digital-physical systems in manufacturing". The technologies that comprise the base of Industry 4.0 are elements such as Artificial Intelligence (AI), Internet of Things (IoT), Big Data, Cloud Computing, Additive Manufacturing (AM), Augmented reality (AR) and Machine Learning, which have been revolutionizing the manufacturing systems and the quotidian (Yu & Schweisfurth, 2020).

In this context, AM emerged as a technology that mimics biological processes by building parts, additively, in layers. The manufacturing process starts with the creation of a 3D digital model, using 3D modeling software or reverse engineering techniques (Bacciaglia et al., 2020; Rayna & Striukova, 2016). Although the technology itself is old, it's only gaining visibility in the past few decades as globalization brought the need to increase differentiating factors, as a way to overtake competitors. Consequently, regulatory pressures to reduce environmental footprint also came and, in order to escape from penalties, organizations where obligated to rethink their business resulting in new and innovative ways to provide value to consumers (Esmaeilian et al., 2016; Öberg et al., 2018).

Due to the accelerated pace of innovation, businesses have been exploiting these disruptive technologies from Industry 4.0 to increase competitiveness and diminish the time launch of products making it possible to hit markets fast (Gwangwava et al., 2018). In the context of Industry 4.0, AM emerges as a key technology to this digitalized and smart era, enabling the fast development of products through an additive process instead of the usual subtractive or molding forms of traditional manufacturing (Godina et al., 2020; Sauerwein et al., 2019).

This technology requires the creation of a digital model of the object, usually using a Computer Assisted Design (CAD) modelling software or a 3D scanner, being then ready to start the production process. Although today AM is seen as a way of direct manufacturing, it has started as a rapid prototyping tool (Ford & Despeisse, 2016). Nowadays, as consequence of the dissemination and improvements achieved with this technology, 3D printers became more affordable making also possible home fabrication, enabling prosumerism – where technology users appear both as producer and consumer (Rayna & Striukova, 2016).

2.2.2 Additive Manufacturing Technologies Characterization

Over the years, several AM processes have been developed by which interesting 3D products can be printed. The range of processes varies with the type of material that is being used and with his initial state (Huang et al., 2013). This section will be dedicated to characterizing some of the existent AM technologies such as: Laminated Objective Manufacturing (LOM), Stereolithography (SLA), Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS) and Laser Metal Deposition (LMD) (Guo & Leu, 2013; Huang et al., 2013).

In the case of LOM, the base material is an adhesive-coated sheet of paper. The fabrication process starts by extending a sheet of paper on a platform with a heated roller. The cutting is done using laser and the parts that don't belong to the model are dashed, which makes it easier when it is time to remove. The platform goes down a thickness of a paper to place a new leaf allowing the sequential sheets to attach to each other. The process is repeated until complete all the necessary layers (Guo & Leu, 2013). A variety of materials can be used besides paper, including metals, plastics and synthetic materials. LOM has some Z-axis accuracy problems and postproduction time is required to eliminate waste (Huang et al., 2013).

SLA utilizes a photopolymer resin and a UV laser that polymerizes the resin. The process itself is very simple because it is only necessary to convert the CAD model into a STL file, and then the rapid prototyping (RP) machine processes the STL file creating slices of the model. This type of process requires a support structure that is built with the model (Guo & Leu, 2013). On each layer, the laser traces on the surface the liquid resin to solidify the pattern. Some cons of this process are that the models are fragile and sticky, resins normally are toxic which entails that the space where the products are being produced requires ventilation and the product size is relatively small (Huang et al., 2013).

FDM is an extrusion-based process that uses thermoplastic filament to build the model and needs a support material, such as wax. The process starts with the liquid thermoplastic being extruded from a moveable head onto a platform, that is kept at an inferior temperature promoting the solidification of the layer (Nurhudan et al., 2021). FDM has a low maintenance cost, however it presents some disadvantages such as support requirement, delamination and poor surface finishing (Huang et al., 2013).

SLS is a process that utilizes material in a powder form. The range of materials that can be used varies from polymers and ceramics to metals. The layer creation technique used in this process is laser scanning, i.e., with a roll the powder is spread on a surface, creating a powder bed that then is scanned selectively by a laser beam that fuses and sinters the particles of the material that belong to the model (Huang et al., 2013). After each cross section on the surface is scanned, the existent powder bed is lowered one layer thickness allowing the formation of a new layer by spreading on top more powder. The process is reiterated until the part is completely built. Contrary to SLA or FDM, this process does not need a support structure because the powder that is not scanned functions as a support material (Guo & Leu, 2013).

LMD is a manufacturing method that builds up parts using metal as raw material. This process essentially consists of a high-power laser beam that locally heats the substrate of metal completely melting it, which results in fusion bath (Guo & Leu, 2013). Further through a nozzle, metal powder is fed to the fusion bath and, by effect of the high temperatures, they mix. In the end, when the mixture crystalizes, welded cords are generated producing structures on the substrate (Kovchik et al., 2019). Thus, with LMD is possible to create very thin walls and repair/ protect applications from deterioration (Guo & Leu, 2013).

2.2.3 Additive Manufacturing and Other Technologies from Industry 4.0

Combining AM with other technologies of Industry 4.0 enhances the potential of this technology, being an example of that smart factories (regardless of barriers and impacts, which will be addressed further ahead). The term smart factory appears as a key concept of this new era and it's empowered by AM, AI, IoT, AR, Big Data, Machine Learning, Blockchain and Robotics (Baroroh et al., 2020; Osterrieder et al., 2020).

Smart factories, as described in literature, are characterized as "highly digitized, agile and connected production systems" that "(…) by generating, transferring, receiving and processing the necessary data to conduct all required tasks for producing all kind of goods" (Godina et al., 2020, p. 5; Osterrieder et al., 2020, p. 1). This novel concept of manufacturing leaves underlined the idea of Cyber-Physical Systems (CPS) as a way to manage and leverage the connection between physical factory floor and computational resources (Lee et al., 2015).

The relevance of this new approach holds on the fact that manufacturing paradigm is likely to shift from mass production to mass customization, as consequence of consumers taking a more active voice in the production process, either as co-innovation agents or from choosing predetermined options to compose the final product to better satisfy them (Chan et al., 2018; Rayna et al., 2015).

In general, the current stages of implementing AM in production process can be summarized in three main parts (Wong & Hernandez, 2012):

1) Creation of the model/ reverse engineering;
2) Printing;
3) Finishing process.

Regarding smart factories, the essence remains the same, although the production process is more elaborate because of the inherent interaction between the technologies above mentioned. First, it's necessary that the customer specifies the requirements for manufacturing, resulting in the creation of a digital twin for production, which can be done using Blockchain technology. At this point, the individualized manufacturing process is set in motion (Burke et al., 2017; Mandolla et al., 2019). Due to their modular nature, these types of factories have the capability to flexibly change and reconfigure themselves in order to rapidly respond to customers' needs, consequently to products changes (Napoleone et al., 2020). The technology beyond these changes is IoT, supported by Big Data, who monitors production in real-time (Godina et al., 2020). Since manufacturing is shifting towards a zero defect and high-quality paradigm, allying Robotics with Machine learning allows to merge the accuracy of a robot with the ability and flexibility of a human – Collaborative Robots (Reinhardt et al., 2020). These collaborative robots, also known as Cobots, support smart inspection and corrective actions for quality control systems, by controlling and identifying process deviations (Brito et al., 2020). Relatively to AR, this one is used to assist maintenance personnel with maintenance and repairing equipment, like 3D printers (Burke et al., 2017) or for structural monitoring in high-level industrial fields as aerospace (Marchi et al., 2016). Finally, AI takes part in this process by scheduling the running operations.

Joining all those technologies increases processes' reliability and effectiveness, making viable the introduction of additive manufacturing in industries such as aeronautic or health (Ford & Despeisse, 2016; Mandolla et al., 2019).

2.2.4 Additive Manufacturing Applications

AM has been used in many sectors, as a rapid prototyping tool or a direct manufacturing way, such as automotive, education, construction, aerospace and medicine among others (Guo & Leu, 2013; Gwangwava et al., 2018).

Applications in the medical sector are revolutionizing this field, allowing the construction of highly personalized products and assisting surgeons in detailed surgical interventions. This is a game changing (Guo & Leu, 2013)opportunity because, by illustrating the procedures, novice surgeons can gain practice in high difficulty situations without putting in danger the patient (Aimar et al., 2019). This technology also allowed advances in bioprinting, making it possible to print organs (Ford & Despeisse, 2016; Gwangwava et al., 2018).

Automotive manufacturers were one of the first adopters of this technology and, as leaders in modern production development, they helped to spread the implementation of AM through production systems (Delic & Eyers, 2020; Paritala et al., 2017). The applications in this area are the production of generic components, and as AM becomes a standard practice in vehicle production, it is expected that this technology will be used to produce engine parts and critical components (Delic & Eyers, 2020).

It has also been seen the adoption of AM in industries such as aerospace, where they need a small number of component but highly complex (Ford & Despeisse, 2016). In this industry, AM is not only used to build parts but also to repair aircraft engine parts, allowing to reduce cost at the same time extending the lifetime of other components, such as compressors, for example (Guo & Leu, 2013) .

Regarding construction, AM has the potential to replace the current methods and introduce new rationales concerning assembly construction and manufacturing. This is a consequence of AM nature which gives flexibility to switch between materials or alter products properties during printing

(Pajonk et al., 2022). Some current applications of this technology in the construction field are concrete printing and metal parts printing, for example (Paolini et al., 2019).

2.2.5 Impacts and Barriers of Adopting Additive Manufacturing

Organizations are seeking new ways to create and capture value in order to leverage new business opportunities. AM, because of the attention that has been receiving, has become one of those instruments used to achieve differentiation, resulting in competitive advantage (Chan et al., 2018). However, thanks to its disruptive nature, it has been impacting businesses, in positive and negative ways (Ford & Despeisse, 2016). One of the positive effects that can be pointed out is that supply chain flexibility (SCF) and supply chain performance (SCP) are improved, because the adoption of AM enables flexibility in terms of production, postponement and sourcing flexibility, helping suppliers to respond to changes without excessive performance losses (Delic & Eyers, 2020). The maturity and availability of new materials helps to extend the use of this technology to numerous industries such as automotive, where AM can contribute to product life extension (Sauerwein et al., 2019). It allows the production of a specific part, that may not be commercialized anymore, to replace a component instead of discarding the product, also encouraging organizations to adopt strategies like product-as-a-service (González-Varona et al., 2020). This shows how AM fosters circular business models (Sauerwein et al., 2019).

Moreover, reconfigurations within the value chains, as result of AM adoption, are also seen as positive effects because production will become more localized. This leads to shorter and simpler supply chains, which will moderate the environmental impact caused by transportation, while promoting local communities' empowerment (Ford & Despeisse, 2016; Gebler et al., 2014). However, considering an extreme situation, this could lead to a radical reduction on the number of suppliers, where only those who supply the material required to production are needed (Chan et al., 2018).

Intellectual Property (IP) protection issues also appear as a negative effect because counterfeiting, at this stage, cannot be effectively prevented (Chan et al., 2018). Additionally, it is important to remember that technologies do not affect only the organizations, they also impact population health and well-being (Godina et al., 2020).

Alongside the need to balance the pros and cons when adopting this technology, it is imperative to know the barriers imposed to businesses. The perception about AM technology, higher unit manufacturing cost (when compared to traditional manufacturing) and maturity are still the major barriers to fully enjoy the potential offered by this technology (Chan et al., 2018; Ford & Despeisse, 2016).

2.2.6 Business Models and Additive Manufacturing

As result of the digital transformation, businesses are experiencing several challenges as the traditional ways of doing business are being altered. Thus, organizations are being compelled to re-think their business models (BMs) (Ibarra et al., 2018).

BMs illustrate how organizations are structured, what are the key resources and how they run their operations to produce revenue. In other words, what is the logic beyond their business that allows them to conduct and link different activities to satisfy customer's needs (Esmaeilian et al., 2016; Öberg et al., 2018). The importance of developing and employing an adequate business model, aligned with the firms' value proposition, comes from the fact that simply using a good technology is not enough (Chesbrough, 2010). In this section, some examples of BMs enabled by AM will be explored from two viewpoints: type of approach to business and business model patterns (BMP).

According to (Ibarra et al., 2018), there are three types of approach to business aligned with AMs' features, namely service-oriented approach, network-oriented approach, and user-driven approach.

Service-oriented approach. Instead of competing merely on manufacturing costs, organizations expand their role on the value chain by offering a service instead of a product. This approach enables product-service system (PSS) business models. PSS emerged with an environmental mission to bring changes in production and consumption on the way to a more sustainable society. This type of business model focuses on the purchase of utility instead of the product itself, delivering customers' needs and reducing material and energy requirements (Mont, 2002). Some key drivers promoting AM in PSS are "the fact that all the stakeholders in a given chain can connect to one another through web-based platforms, and the rapidness that this form of communication brings about for the actors in responding to the unpredictable changes" as well as the design process that increases at once co-creation and customization (Zanardini et al., 2016, p. 545).

Network-oriented approach. In this case, the value chains are raised beyond individual. This approach enables Peer-to-Peer (P2P) business models. P2P business model is a virtual and decentralized network, whose nodes can communicate directly without an intermediary, for the purpose of selling or buying goods (Hughes et al., 2008). An example of a business model that follows this reasoning is the DMS. DMS is a decentralized manufacturing system that makes use of IT to bring products closer to the customer (Rauch et al., 2016, 2018). With the use of AM, manufacturing does not need to be organized in traditional structures, i.e., with centralized production facilities. Instead, organizations can make use of distributed facilities, allowing organizations to reach global market growth as well as to fulfill local needs (Rauch et al., 2016). This form of production introduces the term of "Glocalization", which lies on several local and self-sufficient supply chains at a global extent. Some drivers for adopting this type of production model are sustainability culture growth, mass customization, market-customer proximity, diminution of logistic cost, democratization of design, regionalism and authenticity (Rauch et al., 2016).

User-driven approach. In this approach, organizations are: (1) responsive to user-driven design, (2) aligned with customer's value creation context and (3) flexible regarding value proposition. An example of a business model enabled by this approach is customer-centric business model. As its name implies, customer-centric business model is a strategic way of conducting business where the customer is at the center of firm's operations and culture. In this type of model, customers are more involved in firms' activities, either by co-creating or by doing all the creative part (Bogers et al., 2016).

Regarding business models, due to AM technology's nature and maturity, Business Model Patterns (BMP) can provide essential information for the definition of new business models, as a great share of innovations come from reshaping existing patterns (Weking et al., 2020). Thus, BMP are combinations of business model designs that describe solutions to a certain problem and derive from experience, serving as instrument to systematically codify knowledge. In other words, BMP allows to make inferences from previous observations and reuse that knowledge to respond to a new challenge (Lüdeke-Freund et al., 2019).

Weking et al., 2020 identifies three BMP regarding innovation, which can be related to new processes (integration), new products (servitization) or a hybrid between processes and products (expertization).

Integration BMP is related with the enlargement of an organizations' role on the value chain around new processes. Typically, organizations that adopt this type of BMP evolve from focusing on a single part of the value chain to cover more activities (Weking et al., 2020). An example of this BMP applied to a BM is 3DP platform. In this type of BM, what is being offered to the customer is an experience, as a consequence of firms opening their innovation processes and where customers act as a key partner. With 3DP platforms, production is sold as a service, where customers are provided a printing and design service (Rayna et al., 2015). For example, Shapeways is a Dutch-founded 3DP marketplace and service startup that uses this type of BM (Shapeways, 2008).

Servitization BMP is related to the demand-pull for innovation by customers (Orellano et al., 2018). On one side, customers are more demanding and expecting to receive more added value that improves their experience, besides the product itself. This is a consequence of markets dynamics that have been changing and evolving from product consumption optics to a demand focused on results. On the other, customers may only want to receive the value offered by the product use (Frank et al., 2019). A type of business model aligned with this BMP is PSS, that was explained above.

Expertization BMP is related with offering product or process in-house expertise (Weking et al., 2020). An example for this can be the FabLabs. These are digital fabrication labs where customers are given access to 3D printers and knowledge. Thus, it is possible to categorize Fablabs as product and process-relating consultants (FabLab Lisboa, 2013).

Another pertinent aspect of AM and BM literature are the expected impacts of this technology, in terms of the change it will generate on firms. In a review of Jyrki and Mikael (Savolainen & Collan, 2020), the authors discuss two streams identified on academic literature on how AM technologies will be able to impact businesses. On one hand, AM technology can appear as an incremental change and, on the other hand, as disruptive. For each stream they also consider two sides – open and closed – comprising a total of four different, but non-exclusive, directions of development:

1) Closed-incremental stream: AM is a complementing tool and its equipment a natural part of manufacturing.

In this stream, AM technology operates as a part of the manufacturing system who complements mass production and encourages the adoption of product-service models, for example, the digital production of spare parts for cars that are not being produced anymore (Gebler et al., 2014).

2) Closed-disruptive stream: AM becomes a new manufacturing paradigm, compelling organizations to rethink their business strategy.

This describes a scenario where AM technology changes the current dynamic of global value chains due to the increasing of more localized productions and the democratization of manufacturing, making room for the emergence of 3DP supercenters (Esmaeilian et al., 2016).

3) Open-incremental stream: Online sharing platforms brings down the barriers to entrepreneurs.

Joining the use of open-source software with the democratization of production contributes to elevate the role of Fab-Labs, enabling peer-to-peer (P2P) based supply chains because of the higher access that entrepreneurs get.

4) Open-disruptive stream: AM enables closed loop economies.

If content to 3D printers starts to be routinely digitalized and transferred as music and movies, a new era is created to home fabrication. On the other hand, this is an opportunity for consumers to start producing at home, without long logistics chains, becoming easier to track material consumption.

Additionally, a business model that has been capturing a lot of attention is remanufacturing, whose drivers are environmental regulations, more awareness from consumers to this type of issues and scarcity of resource, among others (Despeisse et al., 2017). This type of model benefits from the use of AM technology, which emerges as new tool to create and capture value in a sustainable way (Esmaeilian et al., 2016).

2.3 Structural Analysis of Industry

2.3.1 Business Strategy Analysis

As first proponents on Porter's structural analysis, identified in the literature as Edward Mason and Joe Bain – both Professors and Economists – perceived that some existing forces influence firms' competitive strategies and that they needed to be overcame in order to gain market control (Mason, 1939; Wellner & Lakotta, 2020). Thus, as result of that work, Professor M. Porter raised a question concerning: "Why are some industries more profitable than others?", which led to his published works entitled "How competitive forces shape strategy" and "Competitive Strategy" (Wellner & Lakotta, 2020).

In the article "How competitive forces shape strategy" (Porter, 1979), an analytical framework was proposed. This framework aimed to provide a better insight of industry structure by analyzing the five competitive forces – also designated by Porter as microenvironment forces – that shape the environment where an organization operates (Porter, 1979, 1985).

Competition is inherent to any business environment; hence, the way organizations cope with it determines their failure or success in the market (Wellner & Lakotta, 2020). Although this framework has been proposed in 1979 by M. Porter, with the advent of globalization and arrival of disruptive technologies the need to outstand competitor's performance is even more of a pressure point to many organizations (Ćoćkalo et al., 2019).

By virtue of that, it is imperative that firms choose wisely their competitive strategy, that is, how to offer added value to their customers – as process innovation or culture ideals. So, the elaboration and implementation of a good strategy allows organizations to gain competitive advantage regarding their competitors, reinforcing their profit and position. Thus, competitive advantage is achieved through the organizations' ability to create value added (Porter, 1985). Value is defined as the perceived utility that customers are willing to pay in detriment of a specific good or service, i.e., when the willingness of the buyers exceeds the firm's cost (Anderson & Narus, 1998).

Also implicit to the choice of a competitive strategy is the considered industry attractiveness, which indicates how much profitable the industry can be, and competitive position, which reflects a firm's position within an industry. Both factors can be shaped through the choice of a competitive strategy, in order to better suit the firm. However, it is important to keep in mind that strategies with the potential to alter the industry's structure can cause both favorable and unfavorable consequences (Porter, 1985). That said, structural changes can cause variations in the strength of the competitive forces, thus altering industry attractiveness. To prevent that, a trend analysis of the industry is important when it comes to define a strategy.

2.3.2 Porter's Five Forces Model

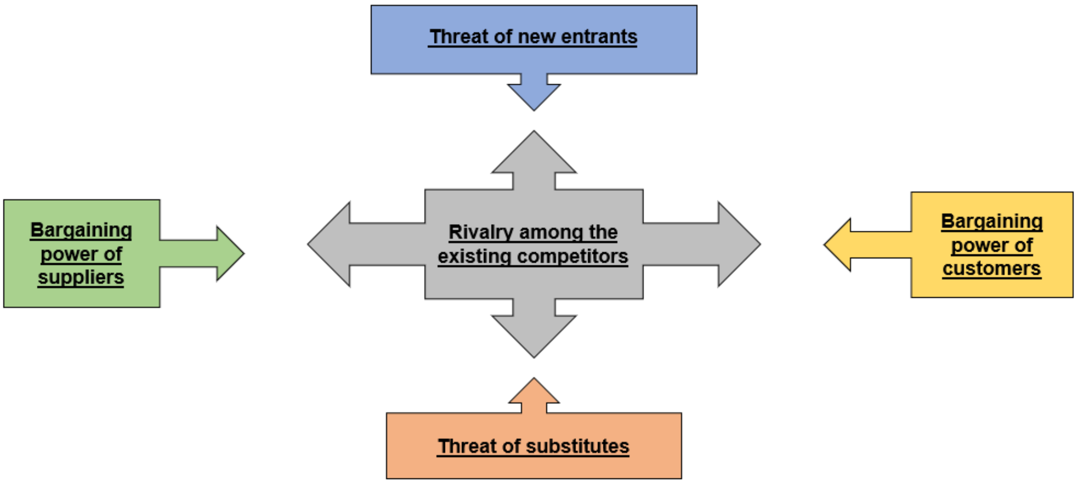

Figure 2.2- Porter's Five Forces model (Adapted from Mortagy, 2003)

The competitive forces that Porter's analysis contemplates are the threat of new entrants entry of new competitors, the threat of substitutes, the bargaining power of suppliers, the bargaining power of customers and the rivalry among the existing competitors (Porter, 1979, 1985; Wellner & Lakotta, 2020).

These forces determine the ability of an organization to prosper in a specific context, by constraining, or not, their capacity in retaining earnings superior to the needed investment. These forces are dynamic, since they change as the industry evolves, and vary from industry to industry. This shows that their intensity is a function of the elements that compose the industry structure, such as economic and technical characteristics (Porter, 1985). Nonetheless, they are not only influenced by intrinsic aspects of the industry, but also by macroenvironment factors – such as technology and innovation or government policies – which means Porter Five Forces model encompasses the assessment of a transactional context rather than simply choice of a right industry (Porter, 2008). Thus, this framework's goal is to assist in the process of identifying critical factors as well as an effective strategic positioning that best suits the organization, i.e., that allows directing efforts into those aspects in need (Porter, 1985).

Eventually, at end of the analysis, a global picture about industry's profitability level can be drawn. Yet, it is determinant for business performance that organizations remain creative when it comes to strategy planning (Porter, 1985; Wellner & Lakotta, 2020).

Now addressing the forces that comprise Porter's Five Forces Model, "Threat of new entrants" is related with the height of existing barriers and expected retaliation from firms that are already settled in the market. Some examples of entry barriers can be (Porter, 1985):

- Economies of scale

- Capital requirements
- Switching costs
- Access to distribution
- Government policy
- Proprietary product differences
- Absolute cost advantage

Thus, the threat of newcomers imposes a ceiling on the industry's profitability. So, if the entry barriers are high, newcomers have more difficulty in penetrating that market which, consequently, contributes to higher profitability to incumbent firms (Porter, 2008; Wellner & Lakotta, 2020).

"The bargaining power of buyers" can also establish a cap on industry profitability, since when buyers detain much power in negotiation leverage, they can capture more value by exerting pressure to force prices down. This can be achieved when (Porter, 1980, 1985):

- Products bought are standardized
- Exists a great share of suppliers
- Switching costs are low
- Volume of customers' orders is substantial
- There are only a few other strong players in the market (buyers' concentration)
- There exists pressure of substitute products

On the other hand, buyers also become more sensitive to prices when products constitute a significant fraction of their costs structure, which makes them bargain harder. Moreover, if the industry's product is too profitable, in some cases, an opportunity for backward integration[1] can threaten incumbent firms (Porter, 2008; Wellner & Lakotta, 2020).

"The bargaining power of suppliers" – which is the flip side of powerful customers – is more intensive if (Porter, 1980, 1985):

- Suppliers' concentration is higher than the industry it sells to
- The associated switching costs are high for firms
- Suppliers serve many industries
- Offered products are differentiated and there does not exist any substitute

These are the determinants that allow suppliers to charge higher prices, limit quality and services or even make industry participants support costs. Thus, when the supplier's side has more leverage on negotiation, it affects industry potential profit and may even threaten incumbent firms with forward integration[2] fitting in as additional competitors (Porter, 2008; Wellner & Lakotta, 2020).

[1] Backward integration is a type of vertical integration - firms bring in previously outsourced operations in-house. In this case, customers acquire the raw materials needed and produce themselves the final product.
[2] Forward integration is also a type of vertical integration, but in this case, suppliers take control over the distribution of their products or services.

Relatively to "Threat of substitutes", it is important to first explain what characterizes two goods as substitutes. First, the fact that they perform the same or similar functions; secondly, the existence of a strong and mutual influence over pricing strategies (Porter, 1980). Hence this places a ceiling on prices, which means that the appearance of substitute products/ services affects industry profitability. Determinants for this force are (Porter, 1985):

- Relative price performance of substitutes
- Associated switching costs
- Buyer's propensity to substitute

Technological changes can also have major impact in this aspect, since unseeingly improvements in unrelated industries can suddenly show up as a substitute product (Porter, 2008; Wellner & Lakotta, 2020).

Lastly, the pressure exerted by all the previous forces confers a certain degree of intensity in industry competition, known as the "Rivalry among the existing competitors" force. The intensity of this force is determined by (Porter, 1980):

- Industry growth
- Exiting barriers
- Fixed costs
- Diversity of competitors
- Size and power of each competitor

Similarly to what happens with the other forces, the intensity of rivalry can have a significant impact on industry profitability, depending on the intensity with which they compete and at what level (Porter, 1985). For example, if industry growth rate is slow, this can very likely lead to fights over market share (Wellner & Lakotta, 2020). In those cases, if the strategy used to combat that is exclusively about price – e.g., price cuts – that can generate highly destructive consequences to industry profitability, since profits will be transferred to customers (Porter, 2008). Therefore, industry leaders carry the burden of having greater impact on industry structure, due to their size and consequential influence (Porter, 1985).

2.3.3 Porter's Generic Strategies

Succinctly, applying Porter's Five Forces model (Porter, 1979) requires defining the relevant industry's aspects, such as industry borders, as well as identifying suppliers, buyers, competitors and manufacturers of substitute products. Then, after assessing all forces, an overall picture about the industry profitability is drawn by analyzing the underlying elements (Porter, 2008).

A structural analysis is the starting point when it comes to plan a coherent and effective competitive strategy. A competitive strategy aims to balance the trade-off between opportunities and threats presented by shaping the forces that operate in the organization's environment (Porter, 1985). For that, Porter proposes three generic competitive strategies: Cost leadership, Differentiation and Focus (Ormanidhi & Stringa, 2008).

Both cost leadership and differentiation arise from a firm's capacity to shape its industry's conditions better than its rivals, since both result from the assets or vulnerabilities that the firm possesses (Porter, 1985). In the case of cost leadership strategy, the competitive advantage of this strategy is based on lower costs (Ormanidhi & Stringa, 2008). The sources of advantage for this strategy are often associated with economies of scale, know-how and market share. However, as strategy definition is reliant on the industry's structure, these sources of advantages may differ from industry to industry (Porter, 1985). This type of strategy puts firms in a low differentiation position, either because they choose to use low-grade materials or labor costs are low. Typically, this represents a situation where firms are operating with standard products (Karnani, 1984). Therefore, only one firm can become the cost leader, otherwise this can trigger disputes and consequently induce devastating consequences to the industry's profitability (Porter, 1985).

Differentiation strategy is based on offering unique value to the customer, which can be delivered in the form of a product, service or marketing approach (Yin et al., 2020). Firms using this type of strategy aim to differentiate themselves from competitors in terms of attributes. Consequently, differentiation strategy adoption leads firms to practice premium prices (Porter, 1985). The logic here is that the attention is not on costs, as they are not the principal strategic goal, but instead on customers' loyalty (Porter, 1980).

Although these strategies often appear to be mutually exclusive (Porter, 1980), differentiation strategy "leads to high competitive strength, which in turns leads to high market share, which in turn leads to low average cost positions" (Karnani, 1984, p. 375). This means that both strategies make it possible to position a firm on a low-cost position, which ultimately traduces in higher profits. Thus, cost leadership and differentiation strategies differ in terms of the competitive advantage – as the latter expects to leverage competitive advantage through differentiation instead of lower cost – but converge in terms of competitive scope, as both target industry-wide (Porter, 1980, 1985).

The third and final generic strategy, focus, branches into two variants: cost focus and differentiation focus. This strategy entails, as the name suggests, focusing on a strategic target (Porter, 1985). As the focus strategy concentrates its efforts on a narrow target, contrarily to cost leadership or differentiation, this logic offers to adopting firms the opportunity to serve more efficiently. Thus, firms can carry it out either by better fulfilling the needs of the target segment – differentiation focus – or by lowering costs when serving the chosen target – cost focus (Porter, 1980). Essentially, both variants exploit the vulnerabilities that industry-wide competitors served inadequately (Porter, 1985). Although Porter only identifies two variants of focus strategy (Ormanidhi & Stringa, 2008; Porter, 1985), in another of his works he leaves implied the existence of a third one – cost and differentiation focus – as a combination of the two discussed variants (Porter, 1980).

Consequently, if a firm desires to be successful and obtain competitive advantage, it must choose the type of advantage it seeks for and within which target. This choice will reflect the generic strategy the firm should pursue (Porter, 1985). The usefulness of developing one of these three strategies is that on one hand they allow to shape industry's conditions to better suit firms' ambitions (Porter, 1980); and, on the other hand, they prevent a firm from positioning itself in a "stuck in the middle" situation that ultimately conducts to no competitive advantage (Ormanidhi & Stringa, 2008). Figure 2.3 illustrates the three generic strategies proposed by Porter accordingly to competitive scope and competitive advantage.

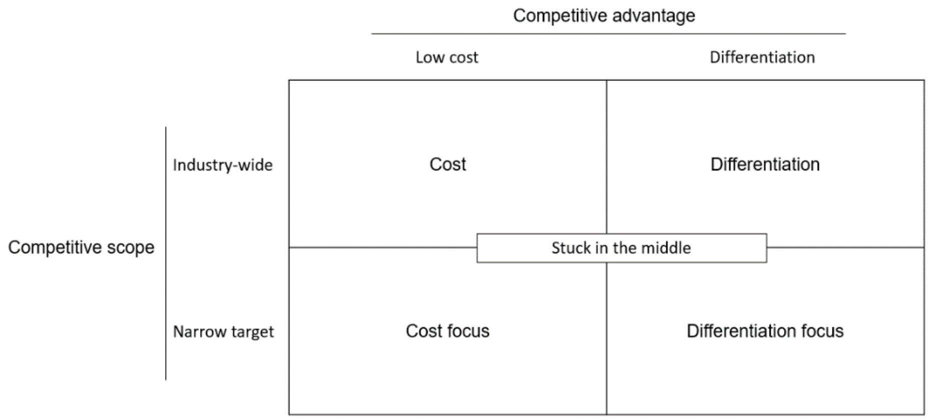

Figure 2.3- Porter's generic strategies (Adapted from Ormanidhi & Stringa, 2008)

2.4 Knowledge

2.4.1 Defining Knowledge

In the literature different definitions are given, but it seems that there is a consensus regarding information as the base of knowledge, although for others data can also act as input (Allan et al., 2004; Rowley, 2007). To better explain why this happens it is essential to introduce the Data-Information-Knowledge-Wisdom (DIKW) hierarchy, a common approach used in knowledge and information literature to define the nature and existent relationship among these entities (Rowley, 2007; Simões-Marques & Nunes, 2016). In general, this hierarchy is graphically illustrated as a pyramid that has at the top wisdom, descending to knowledge, information and where at the bottom is data (Ackoff, 1989; Rowley, 2007). The authorship of this hierarchy is recognized to Russel Ackoff, even if many authors agree (Rowley, 2007) that the conceptualization of the idea that underlies this model first appeared in Thomas Eliot's poem "The Rock" that contains the following lines (Eliot, 1934):

"Where is the wisdom that we have lost in knowledge?
Where is the knowledge that we have lost in information?"

Ackoff classifies this hierarchy as a hierarchy of types, being this "types of content of the human mind" (Ackoff, 1989, p. 3). From his point of view, data is defined as a product of observation – i.e., raw numbers and facts – that have no utility until put in a relevant form, which is equivalent to knowing nothing (Ackoff, 1989; Arpaci, 2017; Rowley, 2007). Thus, it is in functionality that resides the difference between data and information. The latter is obtained by processing data and is this process that allows to "know what" (Simões-Marques & Nunes, 2016).

Knowledge is "know-how" and can be obtained by transmission of information from someone who has it, or by extracting information from an experience. In the literature, other definitions for knowledge exist such as "information made actionable" by Maglitta (Maglitta, 1996) or "Knowledge is the combination of data and information, to which is added expert opinion, skills and experience, to result in a valuable asset which can be used to aid decision making." (Allan et al., 2004, p. 6; Arpaci, 2017). Still, Ikujiro Nonaka proposes another definition for knowledge as "a dynamic human process of justifying personal beliefs as part of an aspiration for the truth". From his point of view, knowledge is a personal belief and, consequently, the need for justification is a critical argument because it establishes the difference between the theory of knowledge creation and traditional epistemology, which sells knowledge as having a "absolute, static and nonhuman nature" (Nonaka, 1994, p. 15).

Finally, wisdom is characterized as the ability to increase knowledge effectiveness, by attaining a deep comprehension about the consequences of behavior that add value. This action is achieved through judgement, which is unique and personal, since it depends on the actor. In other words, wisdom is the understanding of knowledge and thus it has a permanent character unless it is lost (Ackoff, 1989; Rowley, 2007; Simões-Marques & Nunes, 2016).

Now that the entities of this pyramid have been defined, as well as the existent relation among them, it is important to specify the mechanism through which the transition from each stage to the next occurs. (G. Bellinger et al., 2004) suggests that understanding is what gets a stage below to raise to the next. However, this contrasts with the perspective offered by Ackoff that understanding is a stage between knowledge and wisdom, which is a shared view among other sources in literature (Ackoff, 1989; G. Bellinger et al., 2004; Rowley, 2007). That said, understanding can be defined as:

"(…) ability to explain why things are as they are and why the means chosen produce the outcomes they do. It requires diagnosis and prescription, that is, requires detecting error, knowing why it was made and how to correct it." (Simões-Marques & Nunes, 2016, p. 389).

In the case of moving from data to information, understanding refers to acknowledging relations. Since data is discrete and represents a fact or an event, the role of the understanding mechanism is to establish a possible relationship of cause and effect in the form of information (G. Bellinger et al., 2004; Rowley, 2007). From information to knowledge, a parallel with what was previously described can be drawn, but now understanding is about patterns. Knowledge represents a pattern that was inferred from provided information, and that allows to predict situations that are described or will happen in the future (G. Bellinger et al., 2004; Rowley, 2007). From knowledge to wisdom, the moving process occurs by understanding principles. Wisdom is essentially systemic, so in this case there is a deeper assimilation of principles that were already embodied in knowledge (G. Bellinger et al., 2004; Rowley, 2007). Figure 2.4 schematizes the DIKW hierarchy.

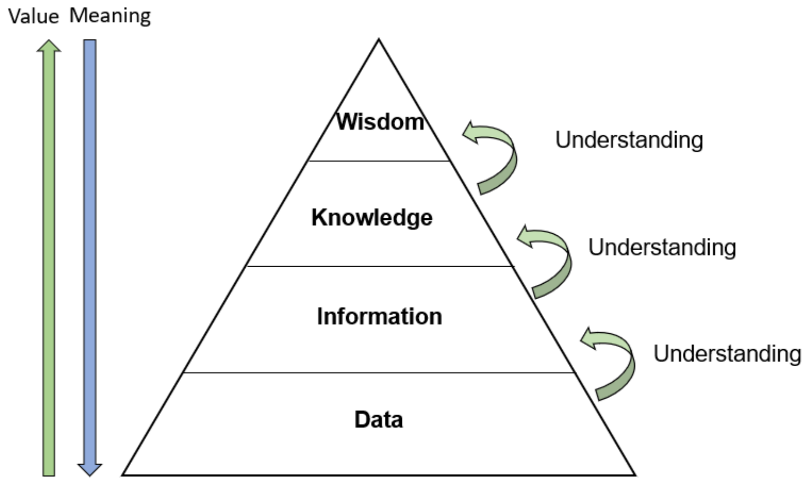

Figure 2.4- DIKW Hierarchy (Adapted from Ackoff, 1989; Rowley, 2007)

Still regarding the concept of knowledge, there exists the need to make a distinction between two types of knowledge – explicit and tacit knowledge.

Explicit knowledge is a type of knowledge that is discrete, i.e., that can be expressed in words and numbers, and is transmittable between individuals in a formal and systematic way. This type of knowledge is shared in the form of data, specifications or scientific formulas which is documented information that facilitates action (Nonaka, 1994; Nonaka & Konno, 1998).

On the other hand, tacit knowledge is a type of knowledge that results from experience – know-how and learning that is embedded in the human mind – and due to that it is highly personal. Since it is rooted in action and emotions, in a specific context, the process of extraction and codification is very difficult. This type of knowledge includes personal insights and hunches (Arpaci, 2017; Nonaka, 1994). Tacit knowledge also involves two dimensions: cognitive and technical. The cognitive dimension centers on elements such as beliefs, ideals, values and mental models that shape the way we perceive the world, through analogies that are created and manipulated in our minds. By contrast, the technical elements encompass personal skills or crafts, usually called know-how (Nonaka, 1994; Nonaka & Konno, 1998).

2.4.2 Knowledge Management

In an economy where organizations face constant uncertainty, the need to coordinate the efforts made by the heterogeneous groups that compose them is a major priority to top managers (Barão et al., 2017; Von Krogh, 1998). Adding to this the constant expansion and complexity of knowledge, a need arises with this new economic era residing on how to manage organizational knowledge in order to extract its full potential value (Lamy, 2014). Although this problematic around knowledge is not new, the fact that knowledge is seen nowadays as the driving force of the organizations gave rise to an increasing and transversal discipline known as Knowledge Management (KM) (Davenport & Grover, 2001; Girard & Girard, 2015; Lamy, 2014). In the literature, the first steps taken towards the concept of KM are credited to Peter Drucker with his work about knowledge workers and knowledge work (Bolisani & Bratianu, 2018; Drucker, 1999b).

Knowledge management refers to a systematic process to identify, create, share, use and manage the collective knowledge in an organization (Arpaci, 2017; Barão et al., 2017). In other words, KM is "the coordination and exploitation of organizational knowledge resources, in order to create benefit and competitive advantage" (Drucker, 1999a, p. 157). That said, it is possible to assert that an effective knowledge management strategy in organizations must focus on knowledge creation and knowledge transfer activities. This can be achieved by exploiting predictive data analysis that allow organizations to identify knowledge that can be transformed as value to an organization, at the same time combating its inherent dynamic nature (Barão et al., 2017).

As organizational knowledge is the main source of revenue of the modern organizations, KM emerges as set of practices that help in the process of identifying the main knowledge processes as well as tracking and keeping tacit knowledge within organizations. That is, KM helps to create a comprehensible notion of how the systematic transfer of tacit to explicit knowledge occurs inside the organization (Barão et al., 2017; Bolisani & Bratianu, 2018). Organizational knowledge is often less than the sum of its parts, as knowledge is not always available to everyone when they need (de Swaan Arons & Waalewijn, 1999). This happens because tacit knowledge is difficult to transfer and document, so with the help of KM the organizations should be capable of identifying which knowledge is critical in order to make it available and shareable to who needs it (Barão et al., 2017). Therefore, KM materializes as a discipline that bridges the operational and strategic management of an organization, allowing the alignment of strategic thinking and design with the strategic objectives (Bolisani & Bratianu, 2018).

One of KM objectives is to ensure that organizations understand what they know and what they need to know to stay or become competitive (Davenport & Prusak, 1998). This objective shows the clear strategic aspect of KM. Other objectives of KM are to disclose and categorize knowledge, to enable its sharing, and to promote valuable knowledge while new knowledge is created (Chopra et al., 2021). All these goals can only be achieved if the organization has the right culture, processes, environment and technological structure.

A proper organizational culture is closely related with a prosperous environment where people feel free to collaborate, share, socialize and learn (Girard & Girard, 2015). For example, in this type of environment, failure is seen as part of the learning process and various times it is failure itself that leads to innovation. A parallel can be drawn to the existent processes used by the organization to identify and categorize knowledge. The processes need to be aligned with the organization objectives and support the organization in understanding what they know, otherwise they are contributing to decrease the knowledge level within the organization (Chua & Goh, 2009). Although what is described above has a significant impact on organizations' performance, the right technological structure is also an important point, especially because of the high volume of knowledge that organizations deal with. A proper technological infrastructure, i.e., with a design aligned with the organizations' processes and that supports them, helps enhancing employees' workflows, empowers employees to make data driven decisions, and facilitates collaboration between groups (Allan et al., 2004).

Concerning AM and KM, the existing literature shows that organizations using AM technology could benefit from the employment of KM to identify critical process variables, understand which data is important to retain during operations and take advantage from that information to prevent defects (Rahman et al., 2022). Besides, the use of Knowledge Management Systems (KMS) to refine and standardize AM data could bridge the existent gap between designers and AM technologies knowledge, helping them making more informed decisions, e.g., which printing solution to choose (Wang et al., 2018).

The application of KM practices to real-world environments still poses, however, some difficulties. First, KM is a recent field of research, where there is the need to expand empirical work based on critical and performative KM (Serenko & Dumay, 2015). Additionally, the scarcity of the existent literature to address the study of KM within small and medium-sized enterprises (SMEs), which are considered the "engine of economic growth" (European Commission et al., 2021), fails to support practitioners. Besides, little attention is paid to practical implications and academic work does not convey readily usable knowledge for the practitioners. This creates a communicational gap between academia and practitioners, that needs to be overcome in order to take advantage of the benefits KM can bring to the organizational context (Massaro et al., 2016).

2.4.3 Knowledge Economy

As previously said, the advent of globalization and emergence of disruptive technologies, that consequently contributed to setting new industries, defined a transition line to organizations in the sense that they imposed higher rivalry tensions (Chan et al., 2018; Powell & Snellman, 2004). For example, due to globalization organizations have moved from competing locally to a global scale which gave customers more buying power, as more choices became available. On the other hand, the exploitation of disruptive technologies, such as AM, enables a faster response to customer needs (Khorram Niaki & Nonino, 2017). The aforementioned led to the strengthening of rivalry (Gwangwava et al., 2018).

Thus, the differentiator factor needs to be in how organizations offer value to customers through services and products, which called for a change in innovative thinking (Nonaka, 1994). Thereby, knowledge has become an increasingly relevant asset for organizations, which gave space to transit from an economy based on material resources to an economy driven by knowledge (Hermelin, 2020). The material-based economy is dependent on assembly lines, where physical inputs are the primary source for production and economic development (Stanbridge et al., 2004). On the contrary, in the knowledge-based economy, the economy is driven by decentralized information and relies on knowledge creation and dissemination (Powell & Snellman, 2004; Stanbridge et al., 2004).

This shift from an industrial economy involved changes on the labor market, namely the need for a higher level of education, as new jobs strongly rely on knowledge-intensive activities (Brinkley, 2006; Hermelin, 2020). Thus, the raw material of the knowledge era is the intellectual capital that an organization retains in the form of human, relational and structural capital, i.e., the ability of an organization to capture and institutionalize the knowledge supported by Information and Communication Technologies (ICT) (Adams & Oleksak, 2010; Barão et al., 2017; Brinkley, 2006).

Knowledge-based economies, as any other economy, are susceptible to changes – in this case, because knowledge is dynamic and renewable. However, there are some tools that allow organizations to increase their agility when it comes to respond to those events (Barão et al., 2017; Brinkley, 2006).

2.4.4 Knowledge Generation Processes

Knowledge acts as a crucial resource in contemporary businesses and due to that several questions concerning knowledge creation were raised (Chou & Tsai, 2004). Although nowadays this constitutes a crucial point to organization that hope to thrive, in 1995, Nonaka and Takeuchi had already proposed a research framework where they described knowledge creation processes. This framework embodies two dimensions: epistemological and ontological (Chou & Tsai, 2004; Nonaka & Takeuchi, 1995).

The epistemological dimension focuses on the characteristics of knowledge, allowing the distinction between explicit and tacit knowledge. The continuous dialogue between these two types of knowledge is at center of knowledge creation, since the mobilization and conversion of tacit knowledge drives the creation of new concepts and ideas (Chou & Tsai, 2004; Nonaka, 1994). The second dimension of Nonaka and Takeuchi's framework is ontological, which concerns the levels of knowledge creation entities or mechanisms that can initiate the SECI processes, whether at the individual or organizational level. So, in order to create knowledge effectively, there must exist communication and cooperation between these two dimensions (Chou & Tsai, 2004; Nonaka, 1994).

At a fundamental level, individuals are accountable for knowledge creation – through interactions among them or between them and their environment. The processes that facilitate this are described by SECI model, also known as Spiral of Knowledge (Nonaka & Takeuchi, 1995). This model portraits the movement of knowledge between tacit and explicit through four modes of knowledge conversion, namely socialization, externalization, combination and internalization (Arpaci, 2017; Chou & Tsai, 2004; Nonaka, 1994; Stanbridge et al., 2004). The model is presented in the following figure:

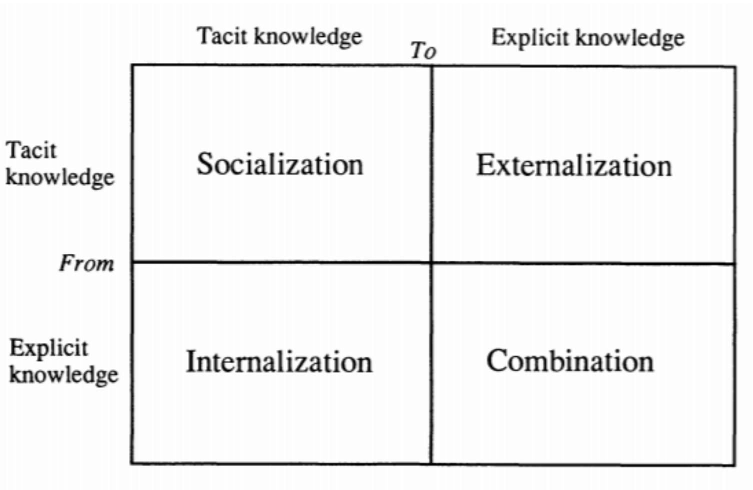

Figure 2.5- SECI Model (Nonaka, 1994, p.19)

Knowledge conversion starts with tacit knowledge that, as said previously, is a type of knowledge that is deeply rooted in action, highly personal and, therefore, difficult to formalize and communicate (Nonaka & Takeuchi, 1995). Through "Socialization" it is possible to exchange tacit knowledge with other individuals, i.e., via shared experiences in which information is transferred – given a certain physical and emotional context – allowing the other to absorb, even without language. On the other hand, it is possible to convert tacit into explicit knowledge. The process that enables this articulation is called "Externalization", where an individual can express his idea through techniques such as metaphors, analogies or narratives, thereby translating it into a readily understandable form that can later be shared with others (Nonaka, 1994; Nonaka & Takeuchi, 1995).

Another mode of knowledge conversion is "Combination" where pieces of explicit knowledge are combined into more complex ones. Social processes, such as meetings or conversations, play an important role in this process, enhancing the ability of an individual to reconfigure information held by others through recategorization and recontextualization of existing knowledge. This interaction creates new knowledge in the sense that new connections are made, by gathering information that already exists, however it does not extend the existent knowledge base (Nonaka, 1994; Nonaka & Takeuchi, 1995). At last, the conversion of explicit into tacit knowledge, designated as "Internalization", bears similarities with the traditional notion of learning. In this process, explicit knowledge is converted into tacit knowledge through a process of learning by doing, where participants in a certain field of action share explicit knowledge that is gradually translated, through interaction and a process of trial-and-error, into aspects of tacit knowledge (Nonaka, 1994; Nonaka & Takeuchi, 1995). This allows to conclude that "action" is profoundly connected with the internalization process, since conversion takes place during the incorporation of explicit knowledge through action and practice.

At this point, a narrow description about the conversion processes inherent to knowledge creation has been given. However, before delving into a more specific perspective, such as knowledge creation at an individual and organization level, there exists the need to expand some concepts that were previously introduced and that play a relevant role in this process (Nonaka, 1994). For example, in externalization, metaphors constitute a fundamental part of the process. They are not a thinking process, but instead a method of perception that enables the experiment of a new behavior through inference from another existent model of behavior. Metaphors present themselves as an effective method for converting tacit into explicit knowledge and support the generation of new knowledge based on existing one. Considering that externalization is triggered by meaningful dialogue, the use of metaphors also allows the acknowledgement of hidden tacit knowledge that otherwise would be difficult to transmit (Nonaka, 1994).

Another technique used to express one's ideas are analogies. Analogies are a cognitive process of information transferring that emphasizes the similarities between two distinct things. While metaphors offer room for free associations, as they are mostly driven by intuition, analogies reduce ambiguity since they refer to things that are already understood, thereby minimizing contradictions that can be found in metaphors. Thus, analogies offer a more structural approach to explore new concepts or systems by bridging the gap between image and logic. It is relevant to characterize and highlight the distinction between metaphors and analogies, because it is the identification of incongruities on metaphors and resolution of them through analogies that turns possible to transform tacit knowledge into explicit knowledge (Nonaka, 1994).

In terms of the theory of organizational knowledge creation, individuals represent the basis, since it is through them that knowledge is amplified and consequently crystallized as a part of the knowledge network of the organization (Chou & Tsai, 2004). Therefore, a symbiotic relation needs to exist between organizations and individuals, as the support given by those entities should provide individuals a context where they can feel creative and encouraged to express their beliefs and commitment, that can later be translated in new knowledge (Nonaka, 1994). Moreover, the individual's commitment is influenced by three elements: intention, autonomy and fluctuation.

Intention is related with how individuals absorb the world around them in order to comprehend their environment. It is through intention that individuals derive meaning from information, which allows them to evaluate the significance and value of the knowledge that is being perceived or created. The previous description acknowledges intention not only as a state of mind but rather as an action-oriented concept, since it relays on the search for meaning (Nonaka, 1994; Popadiuk & Choo, 2006).

Another factor is autonomy, which can be depicted in terms of individuals, groups, or organizations. To simplify the explanation, only the individual perspective is covered. The principle of autonomy is an important condition to individual knowledge creation since every individual has their own personality, which leads to different interpretations about the surrounding world. Thus, the freedom to act autonomously may open a door to new opportunities that otherwise would not be considered. This concept of autonomy allied with a sense of purpose constitutes a trigger to individuals' motivation to form and absorb knowledge (Nonaka, 1994; Popadiuk & Choo, 2006). Lastly, the fluctuation of the environment is also an important condition since individuals are influenced by what surrounds them as much as they influence it (Nonaka & Toyama, 2015). These fluctuations exist because the environment is not static, i.e., it is necessary to take in account the chaos, ambiguity, redundancy, noise and even randomness that characterize every environment (Nonaka, 1994). That said, fluctuations tend to cause breakdowns on "individual's habitual, comfortable ‘state-of-being’" and can manifest themselves as interruptions on routines or habits that lead individuals to questioning the veracity of their attitudes (Nonaka, 1994; Popadiuk & Choo, 2006). It is this process of questioning the basics that often prompts the realignment of commitments. Thus, if individuals can see through the existent chaos and gaps, new relationships can be created (Nonaka, 1994; Popadiuk & Choo, 2006). The need to emphasize the elements that support commitment derive from the fact that commitment is a key component on the human process of knowledge creation (Polanyi, 1958).

After having the support needed to express their beliefs and commitment, individuals are then able to synthesize the tacit and explicit knowledge detained through the conversion processes described by SECI model in a social space. Therefore, social spaces can be described as places where information gains meaning due to interactions between individuals, allowing knowledge to flourish (Chou & Tsai, 2004; Nonaka, 1994; Nonaka & Toyama, 2015).

The introduction of "social spaces" has now opened a door that allows to explore knowledge creation theory at an organizational level. An organization is composed by tangible and intangible assets that are structured and managed in a way to achieve a certain goal (Barão et al., 2017; Ramezan, 2011; Stanbridge et al., 2004). The concept of social spaces allows to approach knowledge creation at an organization as an organization can itself be viewed as a social space, where social units/groups of people are formed to coordinate efforts and share knowledge among themselves (Barão et al., 2017). As knowledge is the primary resource in the actual economy, as discussed previously, the most important assets of an organization are then the intangible assets (Al-Omoush et al., 2020; Ramezan, 2011). Contrasting with the tangible assets (resources that have a physical form such as equipment, inventory or properties), intangible means that their value does not reside on their physical form in nature, but instead on their contribution to operational effectiveness (Barão et al., 2017).

Thus, intellectual capital, that is a set of intangible assets, presents itself on organizations in the form of human, structural and relational capital that can generate more intangible assets such as knowledge through informal activities (Barão et al., 2017; Ramezan, 2011).

Human capital is the stock of the workforces' aptitudes and capacities, such as: knowledge, skills, experience, commitment and competence (Schiavone et al., 2022). Structural capital is the frame of an organization, as it provides the cultural and process principles. It is in this dimension of IC that knowledge processes are included (Li et al., 2021). Lastly, relation capital regards organizations' associations with their external and internal environment (Barão et al., 2017). The relation capital component of IC has a crucial role, particularly in knowledge economy, as organizations can benefit from exploring their relationships with customers and suppliers, either by co-creation and/or co-learning (Martín-de Castro, 2015). However, this will depend on the firms' ability to "recognize the value of new, external information, assimilate it, and apply it to commercial ends (…)" (W. M. Cohen & Levinthal, 1990, p. 1). Moreover, this dimension is positively associated with value creation, as suggested by (Li et al., 2021). Hence, the importance of intangible assets to an organization resides on the fact that intellectual capital is the operationalization of tacit and explicit knowledge (C.-C. Huang & Huang, 2020), which makes it a promoter of knowledge sharing processes (Schiavone et al., 2022). Therefore, the efficient exploitation of IC will allow firms to create more value, consequently enhancing their organizational performance, and overcome the challenges that this digitalized era is imposing (Li et al., 2021).

Anklam, 2007 also points out to another type of intangible asset that exists in organizations – social capital. Social capital of an organization can be described as the network of interactions among people who work in that organization and society, enabling it to function (Al-Omoush et al., 2020). This is only possible if the existent social groups are functioning effectively. As referred previously, the organizational process of knowledge creation starts with enlargement of individuals knowledge within the organization. This process of enlargement materializes through the creation of "fields" or "self-organizing teams" within organizations in which individual members collaborate to achieve a certain goal (Nonaka, 1994). A self-organizing team is a field of interaction that acts autonomously and where personal knowledge is transported into a social context. The process of knowledge creation in these self-organizing teams is triggered by sharing experiences and continuous dialogue. On one hand, sharing an experience with someone is an action that brings people together and imposes a common view to members in the form of tacit knowledge. On the other, it is through continuous dialogue that the common view is conceptualized (Nonaka, 1994).

In sum, the building of "self-organizing" teams within the firm is what induces organizational knowledge creation, by initiating the socialization mode, which is the starting point of SECI model. Then, through continuous rounds of significant dialogue, making use of metaphors and analogies to express and articulate one's perspectives, hidden tacit knowledge starts to reveal. This process then triggers the externalization mode, setting the continuous cycle of knowledge conversion in motion. It is in this aspect that resides the difference between individual knowledge creation and organizational knowledge creation, as in the latter the four modes of knowledge creation are structurally managed as a whole to form a continuous cycle. This emphasizes the importance that "self-organizing" teams represent in organizations, as it is through them that knowledge detained at a group level is heightened to the entire organization (Nonaka, 1994).

3

CONCEPTUAL MODEL

This chapter is dedicated to describing the conceptual model that was developed based on Porter's Industry Structural Analysis model – also known as Five Forces model approach – adapted to the industry using Additive Manufacturing technology which will serve to assess the impact of this technology on business strategy in the case study. This conceptual model emerges from the identification of the different components influencing each force of Porter's model as result of the evidence found in the literature review. Before delving into it, this chapter starts by presenting and contextualizing the proposed conceptual model. After, the influencing factors for each force are explained in detail. To close this chapter, is described the methodology adopted to pass from the conceptual model to the questionnaire as well as the data collection and data analysis methods employed to conduct this study.

3.1 Contextualization

Today the context adjacent to industries is very different from the one Porter has studied and by which he built his five forces model (Porter, 1979). At that time, the motivation was on how to achieve competitive advantage by creating privileged positions against the competition, e.g., by exploiting economies of scale. However, as globalization and disruptive technologies continue to gain force, thus altering industries' reality, the focus nowadays is shifting towards an industry where the combination of technology with knowledge is the actual raw material of organizations. As consequence of that, Information Technologies (IT) are now more essential than just a supportive mean to assess the competitive forces as portraited with Porter's model (Dälken, 2014; Porter, 1979).

During the past decades, AM as a technology has been evolving and so its role in the actual society, being now considered to be the interface between the material economy and knowledge economy. This happens as 3D printers are able to materialize the intellectual capital detained by an organization. For example, in a pre-production phase one's ideas can be reproduced through prototyping for testing (Birtchnell et al., 2017).

From this time forth, the products need to be thought as continuous products which will require new types of business models and new ways to produce them. This is a potential forethought on the future as sustainability paradigm and dematerialization of the economy came to stay (Loy & Novak, 2021). The promises that continuous products can bring to table are the possibility to do upgrades by making use of modularity, i.e., this type of products will permit the replacement or repair of components. Consequently, this characteristic is only possible by using AM along with the establishment of certified swap 'n' go providers, typically manufacturing hubs (Loy & Novak, 2021). Furthermore, the fact that consumers are today more socially and environmentally responsible enables this type of product to emerge with the "right to repair" to customers without breaching warranties (European Parliament, 2020; Loy & Novak, 2021). This is driven by the availability on lifespan information of product that becomes available since AM brings closer the manufacturer and consumer due to co-creation and consumer-centric production paradigm (Naghshineh et al., 2021). Also, the presence of AM can contribute to simplify the complex existing SCs, either by decentralizing or shortening those chains. On one hand, this technology contributes to its shortening, because less people and assembly steps are required and on the other, provides the agility needed to decentralize decisions when market changes occur (Durach et al., 2017).

A summary scheme of the proposed conceptual model is shown on Figure 3.1**Erro! A origem da referência não foi encontrada.** and the explanation of the influencing factors for each force is given in the following sections.

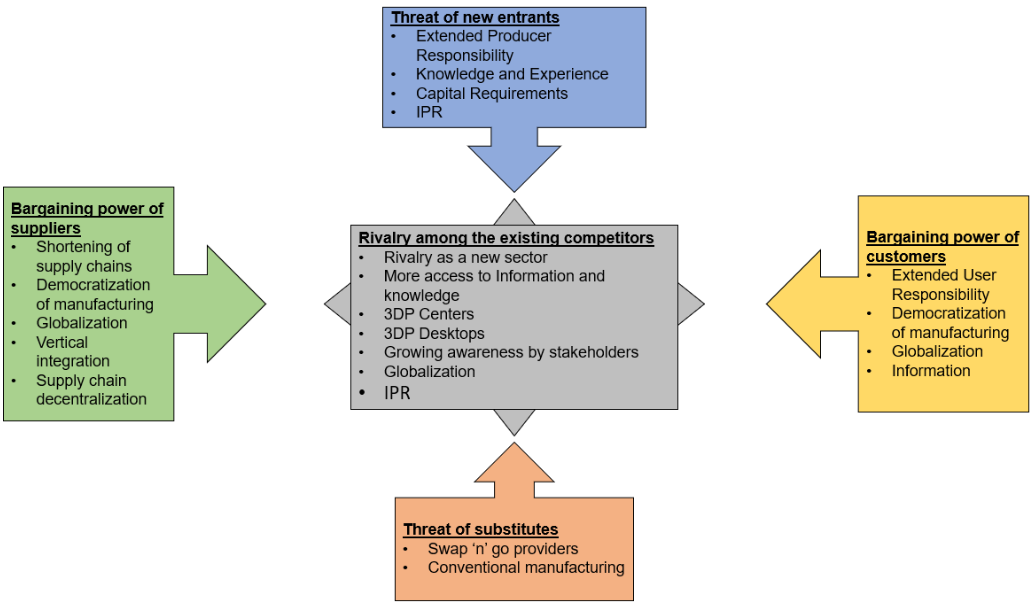

Figure 3.1- Porter Five Forces model adapted to AM industry

3.2 Threat of New Entrants

According to Figure 3.1, starting with the "Threat of new entrants", the factors that will play a significant role are the:

1) Extended Producer Responsibility

Regarding the Extended Producer Responsibility, the European Parliament issued a directive that states that "Member States may take legislative or non-legislative measures to ensure that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products (producer of the product) has extended producer responsibility. Such measures may include an acceptance of returned products and of the waste that remains after those products have been used, as well as the subsequent management of the waste and financial responsibility for such activities" (European Parliament and of the Council of the European Union, 2008, Chapter II). This entails that the producers need to have resources to deal with the product at end of lifecycle, which can be translated in workforce capacity, space and financial funds to realize those activities (Loy & Novak, 2021). This can show up as a barrier to small producers that may want to enter but do not have already the infrastructure needed to accomplish that.

2) Knowledge and experience

Another influencing factor is the knowledge seized by organizations about AM. The employment of qualified workforce becomes crucial since the job now requires understanding and making use of specialized software as well as considerable knowledge in engineering design (Birtchnell et al., 2017; Naghshineh et al., 2021).

Regarding knowledge, universities can also contribute to raising entry barriers in this new era. In this so called "Knowledge economy" universities are lead participants, providing graduate training and research to enrich the scientific field. Nonetheless, universities could operate in a similar fashion as businesses since they produce a great share of the world's intellectual capital. However, the challenge often resides in how to capitalize this knowledge to generate profit (Birtchnell et al., 2017). For this to happen, universities will have to go beyond the activities described above – that has been their mission – and engage with societal needs and market demands. This constitutes universities' third mission and consists of "a triumvirate combining university, industry and government" that links "the university's activity with its own socio-economic context" (Birtchnell et al., 2017). This concept of a third mission, also known as triple helix, emphasizes that communication between distinct parties is crucial for innovation and economic development in a knowledge society. It is out of this interaction that is possible to reinvent institutional and social formats for production, exchange and application of knowledge (Birtchnell et al., 2017). For instance, in the last years, the cooperation between universities and FabLabs is empowering small entrepreneurs as well as organizations, as they give them access to tools and knowledge which enables them to build almost everything. This joining of forces can give an enormous advantage to their beneficiaries as they became part and have access to these knowledge hubs.

As for the experience dimension of the proposed model, as mentioned earlier, this technology has its roots in 1980, although the growth of its use has only started in the past decade. In this sense, early adopters can get advantage from that, as it can be stated that they know the market better.

3) Capital requirements

Regarding costs, the use of AM reduces upfront investments since the free forming nature of this technology eliminates all tooling in the production process (Birtchnell et al., 2017; Bogers et al., 2016). Thus, the capital requirements needed concern mostly software, 3D printers and specialized workforce, either as training or employment.

4) Intellectual Property Rights (IPR)

IPR will also play an important role when it comes to the threat of new entries. For example, when the FDM patent expired in 2009, the monopolistic control over those processes – that at the time was held by the pioneers of 3D printing industry – decreased together with the price of FDM printers. That event brought the opportunity for 3D printer manufactures, like MakerBot, to pave their way selling accessible and consumer-friendly 3D printers (Schoffer, 2016). This means that as 3D printers became abundant, and no legal systems are available for this technology for protecting intellectual properties rights, product designs can be widely distributed, and identical products manufactured without the approval of the rightful owner. The dichotomy around intellectual property rights is that depending on the perspective, they can be an opportunity or a challenge for new entrants (Naghshineh et al., 2021). For instance, if a patent is about to expire, nothing prevents another organization to start quietly developing a system and wait to announce and release when the patent expires. On the contrary, it would give them a huge advantage and consequently raise the entry barriers (Stevenson, 2020).

3.3 Bargaining Power of Customers

Regarding the "Bargaining power of customers", the factors that will influence this force are:

1) Democratization of manufacturing

As AM became more ubiquitous, manufacturing is going under some changes. For example, AM boosts the democratization of the production which gives space to another class of producers called "Prosumers" to appear (Naghshineh et al., 2021). Prosumers are consumers that produce products primarily for their own needs but can also sell them. Although their area of action is not yet regulated, this can be seen as customers gaining power against manufacturers (Botelho et al., 2021).

2) Extended User Responsibility

The introduction of a "Extended User Responsibility" legislation can increase the strength of this force. Given the global efforts to reduce waste by extending products' life cycles, the introduction of a legislation that allows individuals to repair their own products without infringing their warranties will give customers more bargaining power, since they do not need to depend on a manufacturer and instead make use of available information and do it on their own. This can be enhanced by "prosumerism" (Loy & Novak, 2021).

3) Information and globalization

The bargaining power of suppliers has been greatly affected by the progresses made in IT and the development of new technologies during the last years. Customers have now a huge amount of available information which has brought to them various benefits such as increased price transparency, reduced switching costs and ability to compare prices vs quality in a matter of minutes. This is only possible due to the growth of e-commerce that shifted the power to end consumers and allowed them to buy globally (Dälken, 2014).

3.4 Threat of Substitutes

Relatively to "Threat of substitutes", it will strongly depend on the industry. In a broad way and having in mind continuous products, there are two main threats of substitutes using AM technology:

1) Swap 'n' go providers

On one hand, the modularity facet of continuous products empowers the appearance of swap 'n' go providers. A swap 'n' go provider is a qualified manufacturer, certified to make design upgrades or repairs to the product, allowing individuals not to throw away or replace their products. The process can start with an alert that informs the user about the need to a swap 'n' go – this can be initiated in response to a functional requirement. Then the product is printed and installed (Loy & Novak, 2021). For example, this could be used for producing spare parts where the parts would only be manufactured when needed (Rayna & Striukova, 2016).

2) Conventional manufacturing

There are still some aspects where AM is not yet entirely capable to compete with conventional manufacturing. Aspects such as economic feasibility are still a barrier to AM. While traditional processes can take advantage of economies of scale, AM presents itself as a cost-effective option to print products with complex geometry and low volumes rather than large volumes (Pereira et al., 2019). This means that conventional manufacturing can constitute a high threat depending on which industry the organization operates in, e.g., standard products (Pereira et al., 2019).

3.5 Bargaining Power of Suppliers

Concerning "Bargaining power of suppliers", the factors that will influence this force are:

1) Decentralization and shortening of supply chains and "Glocalization"

One of the most popular consequences of AM technology, which can heavily affect this force, is the decentralization of supply chains and consequently its shortening. AM as digital manufacturing technology is digitizing supply chains (SCs) by empowering the shift from physical to digital inventory since, for instance, it is easier for data files to travel than tangible products (Naghshineh & Carvalho, 2020; Verboeket & Krikke, 2019). The decentralization of SCs is threating suppliers' power as "glocalization" is placing the manufacturer closer to the final customer. This phenomenon traduces in fewer stages involved, compared to traditional SC, since less packaging, transportation and warehousing is needed (Naghshineh & Carvalho, 2020). Furthermore, as setup procedures are almost inexistent and processes can be automated and monitored at distance, less people become needed. However, although AM is capable of easing, for example, the existing dependence on component suppliers, the lack of competition existent on material and IT suppliers may balance this force (Verboeket & Krikke, 2019).

2) Democratization of manufacturing

As "Bargaining power of suppliers" is the flip side of "Bargaining power of customers", the democratization of manufacturing also affects this force. With the appearance of the so called "prosumers", suppliers will not only compete with existing suppliers on their industry, but also with this new class of producers which can constitute a threat (Naghshineh & Carvalho, 2020).

3) Vertical integration

As AM turns feasible the alignment of suppliers with the processes of organizations, the implementation of vertical integration becomes even easier, allowing suppliers to take advantage of both the decentralized nature of new SCs and the resources already detained (Butt, 2020).

3.6 Rivalry Among the Existing Competitors

Finally, the strength of "Rivalry among the existing competitors" depends on the pressure exerted by the above forces as much as on the intensity with which firms compete and on which basis they compete. The factors that will influence this force are:

1) Rivalry as a new sector

AM revolution is taking rivalry into a different degree of intensity, where rivalry can now be seen as a new sector. This derives from the fact that "AM allows fast product and process reconfiguration both in volume and design", which opens the possibility to serve multiple markets at once, rather than producing only a specific product (Naghshineh & Carvalho, 2020).

Furthermore, the AM market has experienced an "industry expansion of 7.5 % to nearly 12.8 billion US dollars in 2020" despite the pandemic. Still, this growth is considerably low, given that AM has undergone an average growth of 27,4% over the previous 10 years (Campbell et al., 2021). Nonetheless, analysts are predicting that AM will have an economic impact of 550 billion US dollars a year by 2025 (Thiesse et al., 2015). This indicates that AM market will presumably experience a high growth rate in the next few years.

2) Awareness by stakeholders and globalization

As stakeholders are getting more socially and environmentally conscious, the demand for added-value products with extended life cycles is becoming a reality (Loy & Novak, 2021). This can inflict pressure on this force on the account of globalization as organizations are competing globally, even if they do not import or export goods. Thus, from a strategic point, this demands a focus on customer loyalty to get advantage over competitors, rather than a price strategy.

3) Access to knowledge and information

The progresses made in IT and appearance of disruptive technologies are giving more access to information and knowledge to organizations, which allows them to be more competitive (Dälken, 2014).

4) 3DP Centers and IPR

The increasing availability of 3D printing services, as FabLabs or 3DP Centers, has the potential to empower prosumers by giving them access to 3D printers, which allows them to produce their own products. This can be extended to anyone with or without 3D modeling knowledge, as platforms to share and download 3D models start to emerge. Along with this appears the issue regarding IPR, since no regulation system exists to control these issues (Naghshineh et al., 2021). Therefore, it is plausible that with AM industry rivalry will be intense.

3.7 Proposed Model Application Methodology

As the proposed model is based on non-empirical evidence, a confirmation is required to test its veracity, and consequently eventual applicability.

While the benefits are clear, the transition path for adopting Additive Manufacturing is not obvious. As no firm operates in the same way and each has its own strategy, it is necessary to define means to meet the needs based on the existing infrastructure, culture and technological requirements. The methodology adopted to apply this model followed the guidelines proposed by (Porter, 2008):

1) Identify the relevant industry and boundaries
2) Assess the influencing factors for each force
3) Determine overall industry structure
4) Understand the dynamics of the industry

Regarding the first point, the industry in analysis is Additive Manufacturing, and the boundaries set for this study are only firms using this technology in their productive process.

The questionnaire is the research instrument chosen to respond to the three latter points of Porter's guidelines. To clarify the link between the model and the questionnaire, it is necessary to explain the constructs that allowed this transition. However, it is important to stand out that this model is not a one-size-fits-all solution.

In the case of Threat of new entrants, the factors in test are the ERP, knowledge and experience, capital requirement and IPR. Regarding ERP, to test its feasibility is necessary to understand how organizations stand in terms of product traceability through its life cycle. Only after assessing it is possible to see in what stage organizations are and understand if this legislation can really threat newcomers.

To assess knowledge and experience impact, it is necessary to understand the dynamics around these factors, such as: how many employees are assigned to additive production; the education level of these workers; if there exists difficulty in employing qualified personnel to work with AM; and what are the forms used by the organization to acquire knowledge about this technology.

Regarding capital requirements, it is important to understand which are the investments and how much they spend to run their operation, in the context of additive production.

As for IPR, the focus is on understanding which forms of knowledge protection organizations use to protect the knowledge held in AM technology.

Lastly, to measure the intensity of this force at a broad level, three statements are given where the respondent expresses his opinion in a scale that goes from "Totally disagree" to "Totally agree". The statements are:

- Established firms have the resources to fight the entry of new competitors.
- The entry of new competitors requires large investments in equipment, hand-labor and/or R&D.
- The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights).

Concerning Bargaining power of customers, to appraise the EUR viability, the interest resides on knowing what type of after-sale services organizations offer. This allows to check if customers are provided with support and information, which can result in more autonomy to customers.

As for the democratization of manufacturing, there are two important aspects to assess this factor. On one hand, understand customers' role in product/service development and, on the other, understand if organizations see prosumers as a threat. For the latter, a statement is given to express an opinion:

- Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.

To assess information and globalization influence on customers' bargaining power, it is necessary to know which means organizations use to communicate and share information with customers, especially because the internet allows them to buy globally. To measure the intensity of this force in general, three statements are given for organizations to express an opinion:

- The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.
- Our customers have enough knowledge/information about the industry to assess the quality and value of products.
- Our customers are mainly wholesalers and retailers with the power to influence the purchase of final consumers.

Regarding Threat of substitutes factors, to assess the threat that conventional manufacturing products impose on those producing with AM, in the case of standard products, it is important to find out if the use of this technology is perceived as tool that adds value to organizations. For that, the following statement is given:

- The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.

The viability of swap 'n' go providers' services is tested through a statement that aims to understand the tendency of customers to resort to the after-sales service of the original manufacturer. The statement in question is:

- Customers find it easy to use other firms instead of our after-sales service.

To broadly evaluate the intensity of this force, three more statements are given:

- The needs that our products meet can be met by products from other sectors.
- There is considerable pressure for cheaper substitute products.
- There are substitute products with a better price-performance.

Moving to bargaining power of suppliers, understanding the impact that decentralization and shortening have on SCs depends on knowing what type of relation exists between the organization and its supplier. If suppliers are integrated on the organization processes, it is easier to decentralize the decision-making process, while reducing the resources assigned to those determined tasks. Organizations and suppliers share a common objective, which is the success of the operations, that eventually results in profits for both. Vertical integration likelihood is measured by the suppliers' ability to become a competitor. For that, firms are asked to give an opinion about the following statement:

- Suppliers find it easy to align themselves with our production process.

Like with the other forces, four statements are given so that the intensity of this force can be broadly measured. The statements are the following:

- Suppliers find it easy to raise prices or reduce product quality.
- There are a small number of suppliers that respond to a large proportion of the sector's raw materials.
- Competition is strongly influenced by the bargaining power of suppliers.
- Firms operating in this sector can easily change their supplier.

Lastly, to evaluate the intensity of rivalry among the existing competitors, six statements are given. The intention is to understand if the factors described in the model help to increase, or not, the degree of rivalry in AM industry. The statements are:

- The competitiveness between firms that use Additive Manufacturing is intense.
- There is a wide variety of competitors that use the Additive Manufacturing technology.
- The use of Additive Manufacturing technology allows firms in this sector to serve different markets.
- Changes in our strategy have noticeable effects on competing firms.
- The lack of a regulatory system for copyright presents an opportunity for firms.
- Technological advances allow better access to knowledge of Additive Manufacturing technologies.

As result of these assumptions, the following research hypotheses emerged:

H1: Additive Manufacturing positively influences threat of new entrants.

H2: Additive Manufacturing positively influences bargaining power of customers.

H3: Additive Manufacturing does not influence threat of substitutes.

H4: Additive Manufacturing positively influences bargaining power of suppliers.

H5: Additive Manufacturing increases the rivalry among the existent competitors.

3.7.1 Questionnaire

The questionnaire can be consulted in annex A.1 Questionnaire.

Since some of the contacted firms had already provided some information in a previous survey, carried out within the scope of KM3D project, it was necessary to develop two versions of the questionnaire. Both versions were divided into open and closed answer, multiple choice, and statements where firms were asked to give their opinion. In total, the complete version – which was designed to firms that had never provided information – had 35 questions. Of these 35, 24 are multiple choice, 4 are open answer, 4 are closed answer and 3 are blocks of questions, accounting for a total of 23 statements. To assess the statements, it is used a Likert scale containing options ranging from "Totally disagree" to "Totally agree" and including a "Don't know" option. For the analysis regarding each sector, this scale is graded between 1 and 4 (1- Totally disagree and 4- Totally agree). For the purpose of sectors analysis, answers such as "Don't know" are considered non-answers.

The questions and statements used in the questionnaire were formulated by the combination of the determinants for each factor, provided by Porter's Five Forces model (Porter, 1979), the proposed model and the research hypotheses. The questionnaire was available online from the 2nd to the 12th of November 2021.

3.8 Data Collection Methods

For conducting the case study research, the method chosen to collect data was an online questionnaire.

According to (Cooper & Schindler, 2014) a population is the total sum of elements about which the researcher wishes to make some inferences. To address the questions of this research, the target population for this study are the organizations in Portugal that use AM in their operations. On the other hand, a sampling frame is the list of all those within the population from which the sample will be drawn. The sampling frame used for this study was firms in Portugal that uses AM technologies in their productive process, either as a method for production or as a tool to support it.

The choice of conducting case study research rather than survey research was based on two reasons. First, this research intends to identify "how" and "why" Additive Manufacturing is impacting firms' strategy, which are the rationales of case study. Secondly, survey research is widely used for generalizing, which normally involves using large samples. Thus, case study seemed to be the most suitable method between those two, as this study is built on a limited sample and the rationales "how" and "why" are more appropriate to achieve the proposed objectives than "who", which is the rationale of survey research (Yin, 2003).

The questionnaire was developed to test the research hypotheses derived from the conceptual model, adapted from Porter's Five Forces Model (Porter, 1979). The selection of the questionnaire method was based on the advantages it presents such as reduced cost, reduced time needed to distribute, improved access to sample elements (makes possible to overcome spatial and temporal constraints) and increased convenience (as respondents can complete it at anytime and anywhere) (Cohen et al., 2017). Ultimately, the goal is to identify structural factors that constrain the competitive capacity of Portuguese organizations using AM, so as to assist firms in the process of defining their competitive strategy.

A sampling technique refers to the method that is used to select the members of a sample. The method adopted to select the elements of the sample was expert sampling which is a non-probabilistic procedure. In expert sampling the choice of the elements that compose the sample is determined based on researcher's opinion that the element has the characteristics that are representative of the population (Oliveira, 2012).

3.8.1 Preliminary Test

Since the questionnaire is a fundamental instrument for the research, as is through it that data is obtained, a validation exercise was needed. To this end, a preliminary test was conducted to assess the adequacy of the questionnaire. The test was carried out by researchers of the research project in which this dissertation is inserted, and consisted of detecting corrections that needed to be made as well as validating the logic of the questionnaire. This process preceded the distribution of the questionnaire to the elements of the sampling target.

3.9 Data Analysis Methods

In a first phase, the information collected through open and multiple-choice answers and the statements was analyzed resorting to graphs and tables. For the assessment of each sector concerning the proposed model, the statements given whose purpose was to obtain an image of participating firms' opinion, was employed Grey Relational Analysis (GRA) method. This method is a part of Grey System Theory, which is widely used "for dealing with poor, incomplete, and uncertain information." (Kuo et al., 2008, p. 1). As many statistical analysis methods are based on assumptions such as normal distribution of population and variances of the sample, this method appears as a suitable choice, as for this situation the data available is limited (Wu, 2007).

The procedure used to conduct the analysis using GRA method is shown in Figure 3.2 and described below (Kuo et al., 2008; Wu, 2007).

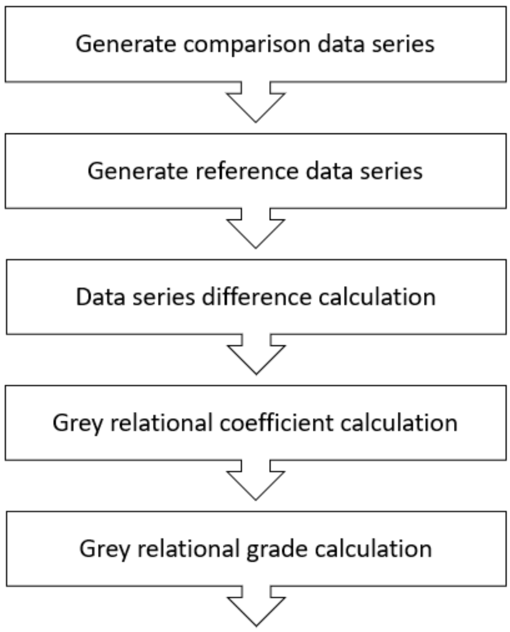

Figure 3.2- Grey Relational Analysis (Adapted from Kuo et al., 2008; Wu, 2007)

1) Generate comparison data series, x_j, for each statement j

To generate the comparison data series for this analysis, the Likert scale used in the questionnaire to assess firms' opinion is converted into a scale of numbers. For "Totally disagree" is set a value of 1, for "Disagree" a value of 2, for "Agree" a value of 3 and for "Totally agree" a value of 4. Answers such as "Don't know" are ignored for the purpose of this analysis. Note that the converted values are arranged into a matrix and each x_j corresponds to a column vector:

$$x_j = (x_{1j}, \ldots, x_{nj})$$

where n represents the number of respondent firms.

2) Generate reference data series, x_0, for each statement j

The reference data series is designed according to the conceptual model, which means that, for each statement a reference value is set. If an agree answer is expected – so as to verify the veracity of the model – the value 4 is defined as a reference; otherwise, the reference is set to 1.

3) Data series difference calculation, Δ_j

The absolute difference between each firm's opinion and the reference value is computed. This absolute difference is calculated for each given statement. At the end of these calculations, a matrix with the difference data series for each firm to all statements is obtained:

$$\Delta_j = \left(\left|x_{1j} - x_{0j}\right|, \left|x_{2j} - x_{0j}\right|, \ldots, \left|x_{nj} - x_{0j}\right|\right) \tag{1}$$

4) Grey relational coefficient calculation

For this step, first it is necessary to find the global maximum ($\Delta\ max$) and minimum ($\Delta\ min$) values in the difference data series matrix. Then, each computed difference Δ_{ij} is converted into a grey relational coefficient γ_{ij}, which is calculated by Eq. (2).

$$\gamma_{ij} = \frac{\Delta\ min + \xi \Delta\ max}{\Delta_{ij} + \xi \Delta\ max} \tag{2}$$

Where:

$\Delta \max = \max\limits_{\forall j} (\max \Delta_j),$

$\Delta \min = \min\limits_{\forall j} (\min \Delta_j),$

ξ is the compensating coefficient of $\Delta \max$ effects, $\xi \in [0,1]$

5) Grey relation grade calculation

Finally, the grey relational grade is calculated for each statement j using Eq. (3). This coefficient corresponds to the average degree of deviance, standardized, from the reference value, which in this study is equivalent to the sector's average concordance with each statement

$$\Gamma_j = \frac{1}{n} \sum_{i=1}^{n} \gamma_{ij} \tag{3}$$

For this analysis, values of grey relational grade inferior to 0,5 will be considered as disagreement. Values superior to 0.5 will be divided into 3 categories: [0,5-0,7] low agreement,]0,7-0,9] moderate agreement and]0,9-1] strong agreement.

4

CASE STUDY

As previously said, case study research is the methodology chosen to conduct this study. As this dissertations' goal is to explore an area of research where tangible and case-based evidence are still scarce, this method appears the most suitable for that purpose.

The firms were selected to participate in the study based on their usage of Additive Manufacturing on the firm's productive process. The universe of respondents is composed by thirteen firms operating in Portugal. Table 1 shows in which economic sector of activity they operate as well as their main business areas.

Table 1- Firms' sector of economic activity and main business areas

Firm	Sector	Main business area
A	Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair	Service provider
B	Manufacturing Industries	Injection Molding in plastic
C	Manufacturing Industries	Car assembly
D	Wholesale and Retail trade; Cars and Motorcycles Vehicle Repair	Trade, maintenance and training
E	Manufacturing Industries	Manufacturing of components and accessories for motor vehicles
F	Manufacturing Industries	Manufacturing of porcelain items
G	Manufacturing Industries	Service provider: Packaging production
H	Consulting, Scientific, Technical and Similar Activities	R&D Projects; Automation projects
I	Manufacturing Industries	Injection Molding in metal
J	Manufacturing Industries	Component manufacturing for the Automotive sector
K	Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair	Service provider: Product development and industrialization (IOT)
L	Manufacturing Industries	Cisterns and toilet accessories manufacturing
M	Manufacturing Industries	Design and manufacture of high precision tools and parts in ferrous metal

Regarding the dissemination method for the questionnaire, the firms were first contacted by email, where a brief description of the research held was given as well as the URL link to access to it.

A second contact was conducted by telephone, where the invitation to participate in the questionnaire was reinforced as well as the author's interest in firms' participation.

The participation of the firms in this study was completely voluntary and all the information collected was handled by the author, anonymously, to guarantee the confidentiality of the participating firms. For this, letters were assigned to each firm, allowing their identification and characterization without compromising their identity. The questionnaire was available online from the 2nd to the 12th of November 2021.

4.1 Analysis and Discussion

To fulfill the purpose of this study, twenty firms were contacted, of which it was already known that they used Additive Manufacturing technologies in some area of their productive process.

Of these twenty, thirteen firms responded to the questionnaire, which corresponds to a 65% response rate.

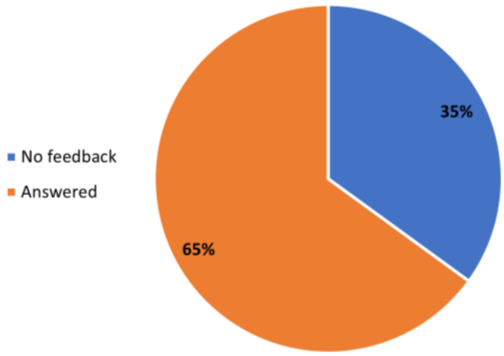

Figure 4.1- Response rate

This section presents a characterization of the respondents as well as of the firm they represent. This section also depicts Porter's Five Forces model (Porter, 1979) in relation to the responses obtained. Then, the three sectors that constitute this samples are analyzed. Afterwards, the answers obtained for each sector are compared with each other.

4.1.1 Respondents' Characterization

The respondents from the firms occupy positions at top/ middle level management. In Figure 4.2 is possible to see the range of positions. The most frequent positions in this sample are Project Manager, Engineering and Innovation Director, R&D Director and Quality Director with 15% which corresponds to two persons performing each of these roles.

Then with 8%, Production Manager, General Director, Technical Director, Manager partner and Owner, which corresponds to one person for each position.

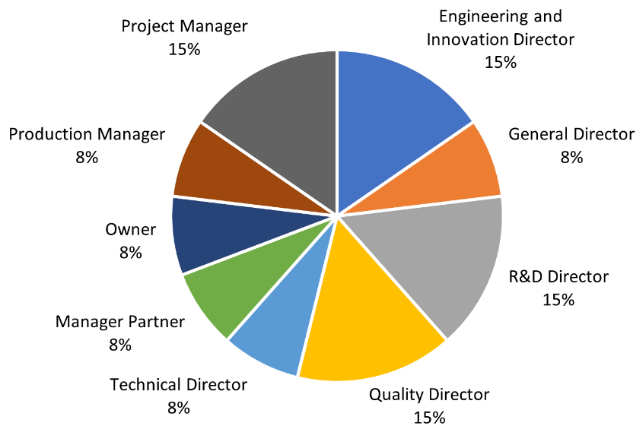

Figure 4.2- Respondents position within the firm

Regarding experience within the firm, most of the respondents have worked there for at least three years, as **Erro! A origem da referência não foi encontrada.** shows.

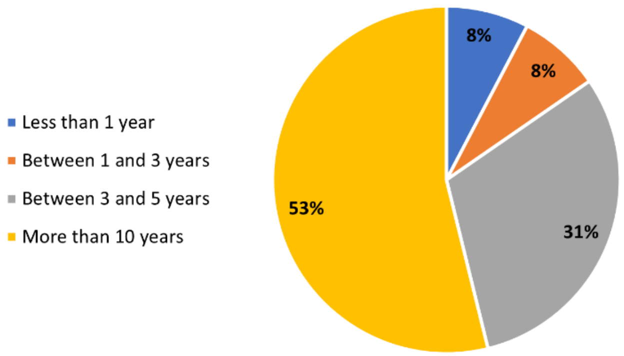

Figure 4.3- Years of experience

As most of them have contact with Additive Manufacturing technology, as Figure 4.4 shows, plus their experience and role within the firm, this sample seems to gather the characteristics needed for this study.

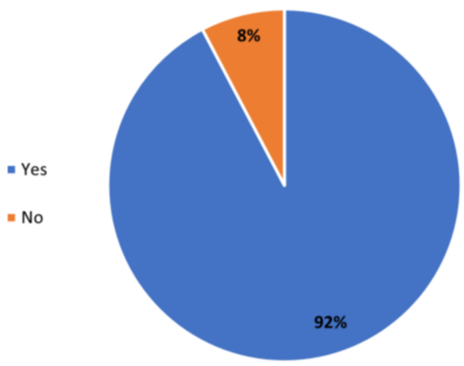

Figure 4.4-Contact with Additive Manufacturing technology in current role

4.1.2 Firms' Characterization

From the thirteen responses obtained, it is possible to observe that the participating firms are in three distinct sectors of economic activity. Figure 4.5 shows that most of the participating firms work in Manufacturing Industries (69%).

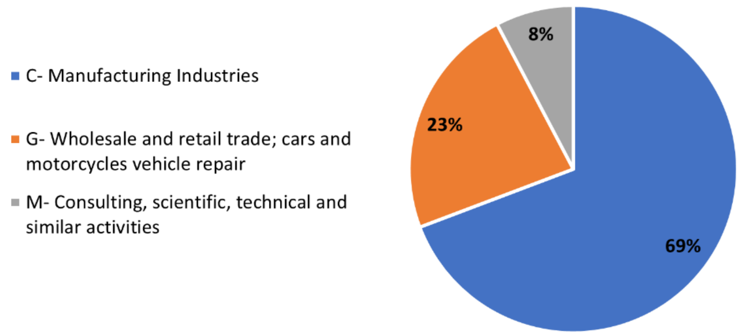

Figure 4.5- Economic sector of activity of participating firms

Regarding location, four firms are placed in Lisbon (29%) followed by three in Aveiro (22%) and two in Porto (14%). From the participant firms there is one that is located both in Lisbon and Castelo Branco. Figure 4.6 shows the distribution of the analyzed firms' locations in Portugal.

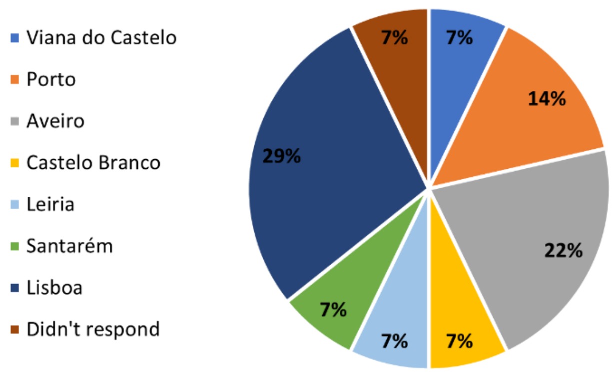

Figure 4.6- Participating firms' location

Concerning the annual turnover, the participating firms fall mostly in "More than 50 000 000€" and "More than 2 000 000€ and less than 10 000 000€", each with 31% corresponding to four firms. Figure 4.7 shows the information described above.

Concerning the number of employees, as Figure 4.8 shows, 38% of the inquired firms have "More than 250" employees, followed by "Less than 10" and "Over 50 and under 250" employees with 23% and 8%, which corresponds to one firm, with "More than 10 and less than 50" employees. However this should follow the same trend as the annual turnover, as these are the two criteria that define a firm in terms of business size classification such as micro, small, medium-sized or large enterprises.

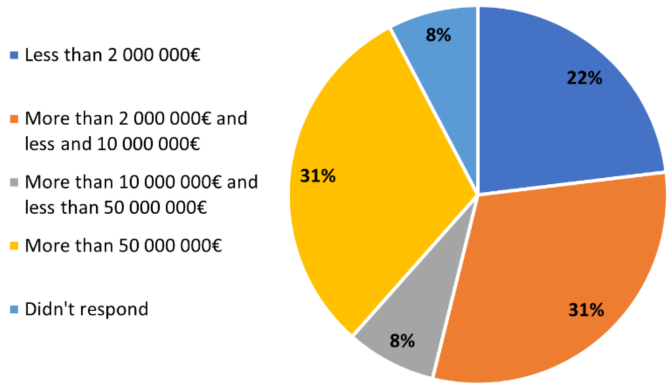

Figure 4.7- Annual turnover

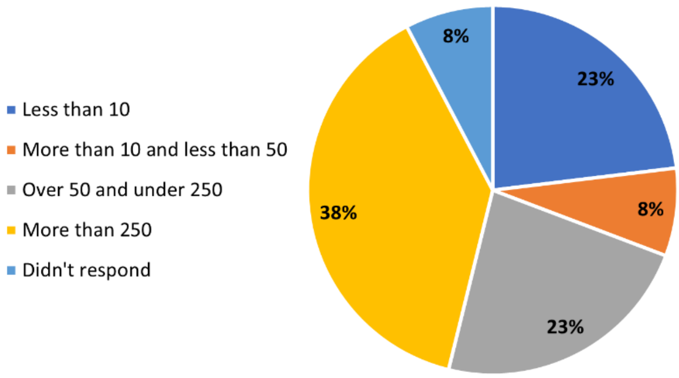

Figure 4.8- Number of employees

Classifying each firm by those two criteria separately would lead to different conclusions. In terms of "Number of employees", this sample is composed by three microenterprises, one small enterprise, three medium-sized enterprises and five large enterprises. By the criterion "Annual turnover", this sample is composed by three microenterprises, four small enterprises, one medium-sized enterprise and four large enterprises. This indicates that there are four firms that, although due to the number of employees should be in a higher classification, the business volumes are lower than the expected for that same classification.

In Figure 4.9, the main areas of business of the participating firms are shown. The top 3 of business areas from this sample are:

1) Service provider;
2) Automobile;
3) Molding injection.

As service providers there are three firms, one specialized in the production of aluminum packaging and the other two in product development. In the automobile sector there are also three firms, one that is specialized in car assembly and two that manufacture components and accessories for motor vehicles. Each of these two areas has a weight of 22% of the total sample.

In injection molding there are two firms. One works with plastic and the other with metal. Together they make up 14% of the sample. The remaining areas are occupied by one firm and have a weight of 7% of the total sample:

1) Trade, maintenance and training about laser cutting equipment's, CNC machining and 3D printing;
2) Production of porcelain items for domestic and hotel industry;
3) Automation projects covering activities such as: Project Management, Electrical Design, Electrical Installation, Automaton Programming, Robot Programming;
4) Research and Development projects, in the area of mobile robotics, development of industrial and management software, plug and produce solutions;
5) Production of items for sanitary industry, such as cisterns and toilet accessories.

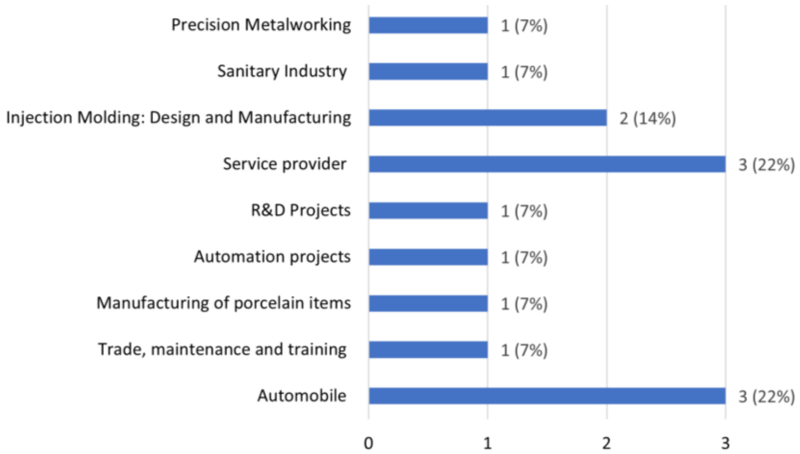

Figure 4.9- Business areas of the participating firms

About market share, most of the participating firms have less than 10% of the market share. Seven firms (54%) have "Less than 5% of the market share" and one (8%) has "Between 5 and 10% of the market share". Three firms (23%) have "Between 20 and 40% of the market share" and two firms (15%) have "More than 50% of the market share". This information can be seen in Figure 4.10.

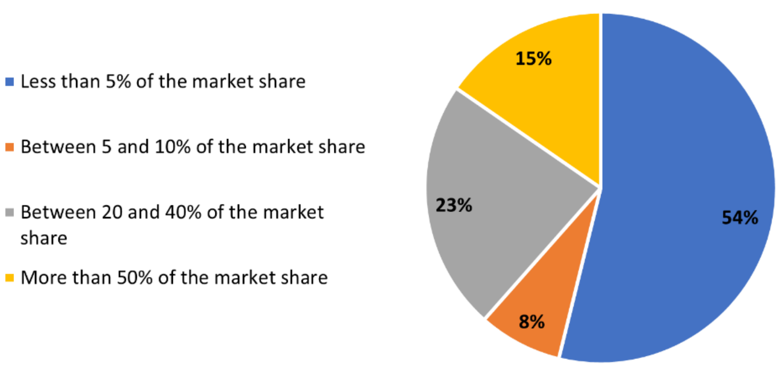

Figure 4.10- Market share

Regarding the usage of Additive Manufacturing technology, most of the firms use it for prototyping for internal use (69%, which corresponds to 9 answers), production of components for internal use (54%, which corresponds to 7 answers) and presentation models (54%) for clients. Figure 4.11 shows the purposes for adopting AM and response frequencies.

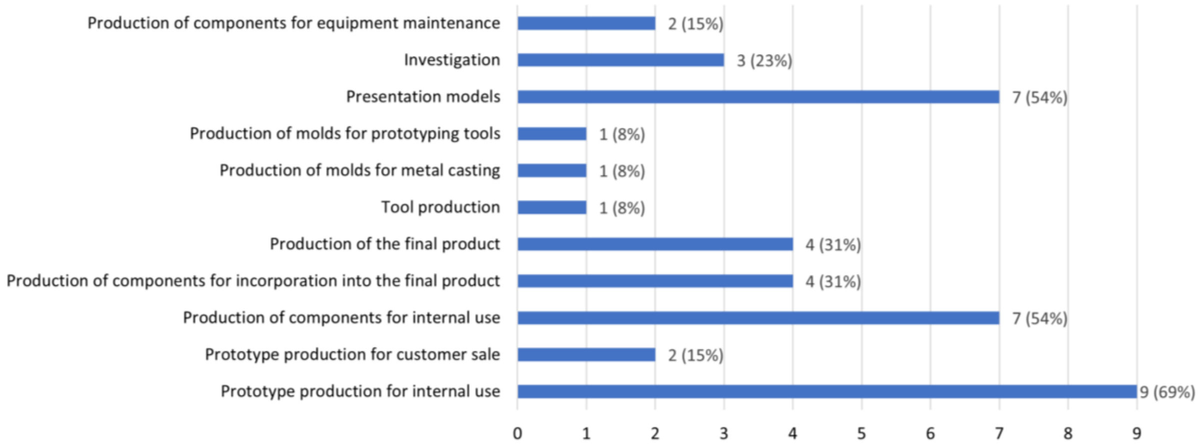

Figure 4.11- Additive Manufacturing usage purpose

Although many of the participating firms use Additive Manufacturing technologies for prototyping and production of components, either for internal use or for incorporation in the final product, it is important to highlight that there are four firms, corresponding to 31%, that use these technologies to produce final products.

Among the participating firms, the use of Additive Manufacturing technologies for the production of tools, production of molds for metal casting and production of molds for prototyping tools are the least mentioned.

As for the type of Additive Manufacturing technology used, four technologies standout: FDM, SLA, SLS and 3DP. All with a weight of 31%, which corresponds to four answers. Figure 4.12 shows the AM technologies employed by the participating firms and usage frequency.

The incidence of response on the aforementioned technologies would be expected as they are

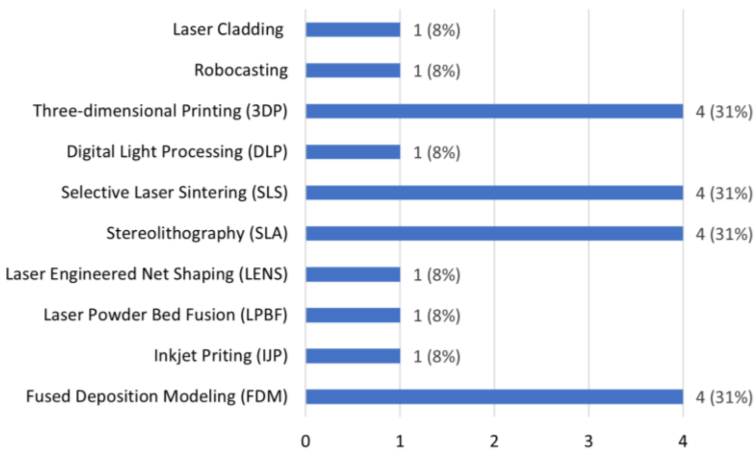

Figure 4.12- Types of Additive Manufacturing technology used

widely used technologies for rapid prototyping and are relatively fast printing, which coincides with the information provided above regarding the purpose for which firms use Additive Manufacturing technologies.

As many of the participating firms use Additive Manufacturing technologies to support their production process, it becomes necessary to know which other production methods are used simultaneously with the Additive Manufacturing technology.

As Figure 4.13 shows, many of the participating firms uses CNC machines (54%) and machining (46%). Among these, five firms use simultaneously both CNC machines and machining in their operations. Of the participating firms none uses waterjet cutting.

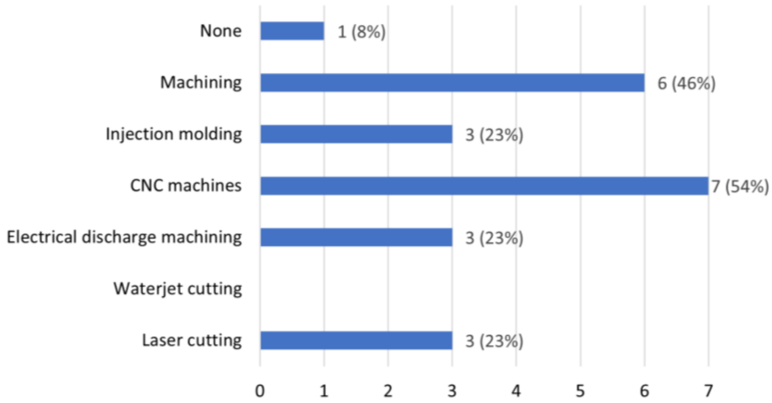

Figure 4.13- Traditional manufacturing processes used by participating firms

Another fact in Figure 4.13 is that one firm fully uses Additive Manufacturing technologies to carry out its production operations.

In this figure two firms are not represented as they affirmed that their use of Additive Manufacturing technologies is exclusively for prototyping and support, not specifying which processes they use in their production process.

Figure 4.14 shows for how long participating firms have been using AM technologies, and Figure 4.15 the weight that production using AM technologies represents on their business. Most of the firms use Additive Manufacturing technologies for at least 3 years.

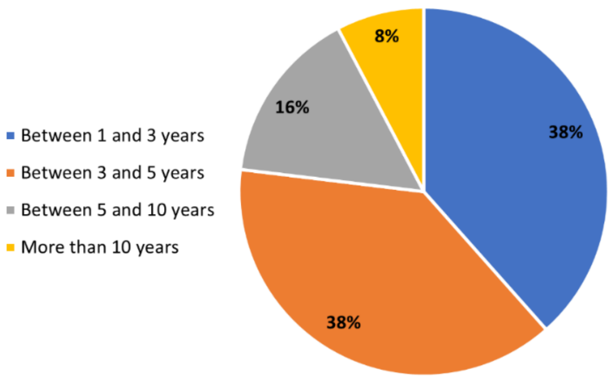

Figure 4.14- Years using AM technologies

According to **Erro! A origem da referência não foi encontrada.**, only one firm confirms that the weight of production using Additive Manufacturing technologies is greater than 50%. This corroborates the conclusion drawn from Figure 4.13, namely that only one firm uses exclusively Additive Manufacturing technologies as production method.

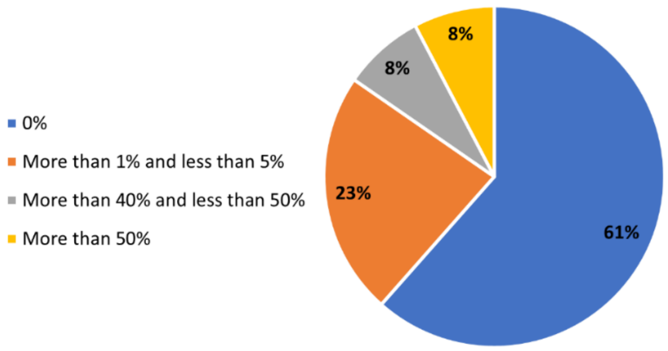

Figure 4.15- Weight of production using AM on the business

The fact that 61% of the participating firms, corresponding to eight, acknowledges that production using Additive Manufacturing constitutes 0% weight of their business also supports what is seen in Figure 4.11, which is that the most mentioned purposes are prototyping and production of components for internal use, or presentation models for clients.

Among the areas of the production process that benefit the most from the use of Additive Manufacturing technology, according to the participating firms, are Design (69%), Adaptability (38%) and Production Flexibility (38%). This information is available on Figure 4.16. Although with less frequency, areas such as waste, product customization, production speed, solution testing, prototype production, supply chain are also mentioned. According to the participating firms, the use of Additive Manufacturing did not benefit batch sizes.

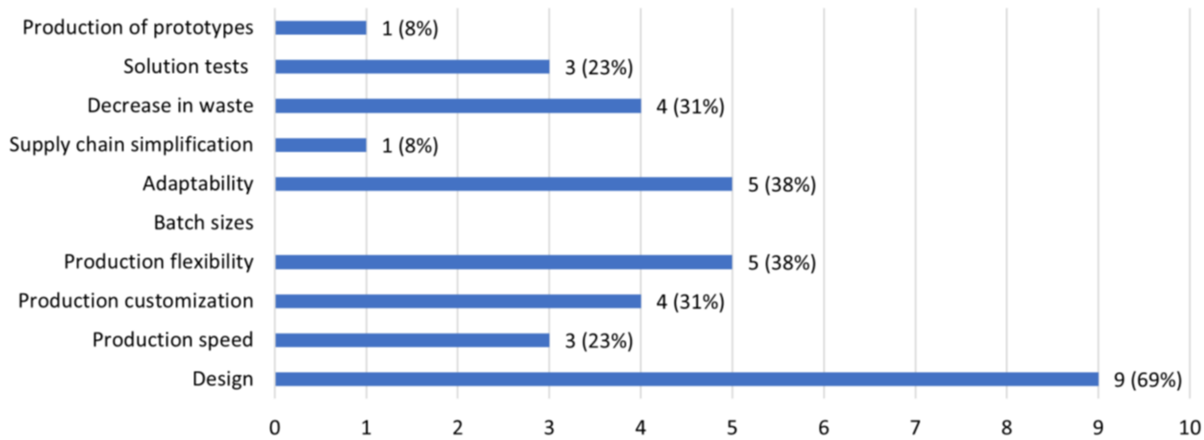

Figure 4.16- Benefited areas due to the use of Additive Manufacturing technology

4.1.3 Model Application Results

According to the proposed model, the factors that would influence Threat of New Entrants are:

1) Extended Producer Responsibility
2) Knowledge and Experience
3) Capital Requirements
4) Intellectual Property Rights

Extended Producer Responsibility. To test the feasibility and time required to introduce EPR, the participating firms were asked about the level of traceability of their products/services. Figure 4.17 shows the possibilities and frequency of each.

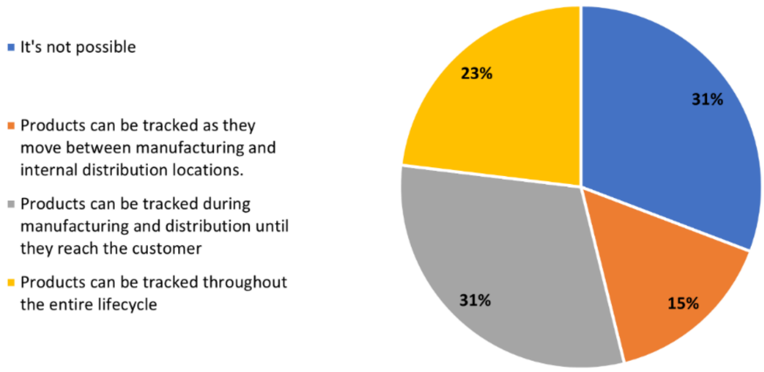

Figure 4.17- Traceability of the products/services offered

Most of the firms, except 31% that corresponds to four firms, can track their products/services. However, from those who can track their products, only three firms (23%) can follow their products throughout the entire lifecycle. These firms are the ones who work with the automobile sector. This means they can accept returned products and residues that remain after usage and give them proper treatment, especially in this case where the firms in question are large enterprises.

Firms that work in sectors like the automobile are already prepared to implement the Extended Producer Responsibility law since it is already possible to know the origin of the products through the serial numbers on it.

For the remaining participating firms, some efforts need to be put in this matter as organizations such as United Nations are setting pressure on countries and firms regarding sustainable practices.

Thus, for firms to be sustainable beyond production, they also need to promote sustainable consumption. For this, they can contribute by reducing the generation of waste through prevention, reduction, recycling and reuse. This can be more easily achieved if the products can be tracked throughout their entire lifecycle.

Knowledge and experience. The focus is to identify how many employees work with Additive Manufacturing technologies, their education, whether there is difficulty in recruiting qualified personnel to work with Additive Manufacturing technologies and how firms acquire knowledge about Additive Manufacturing technologies. According to Figure 4.18, even though the firms in study are mostly medium-sized/large enterprises, the number of employees allocated to additive production is a maximum of 10, given that they mostly use Additive Manufacturing to support rather than to produce.

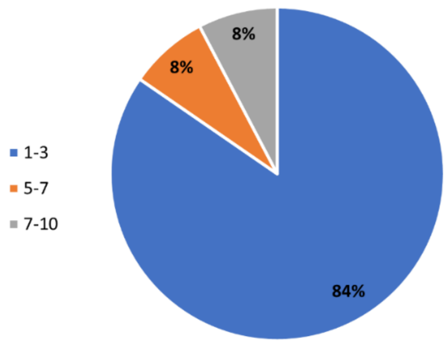

Figure 4.18- Number of employees for additive production

For these same workers, the most advanced level of education is, in general, bachelor's degree (69%) as Figure 4.19 depicts. The absence of professionals with a PhD level of education may be due to fact that AM technology opportunities have only been noticed in the last decade. Besides, many firms only use it to support rather than to produce, hence this does not constitute an attractive situation for professionals with that academic background.

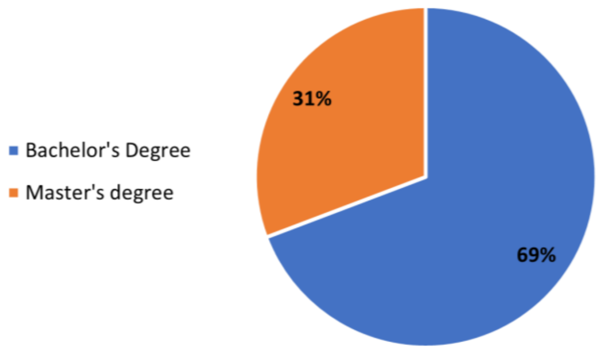

Figure 4.19- Level of education

About whether there is difficulty in recruiting qualified personnel to operate with Additive Manufacturing technologies, most of the firms (77%) agree that it is difficult, as shown in Figure 4.20.

Of those who agree, the most frequent justification is the lack of personnel with adequate training, or that those who have the knowledge are makers who have other areas as their training and profession, working on it only as a complement or hobby, not being available to enter the labor market purely in this area.

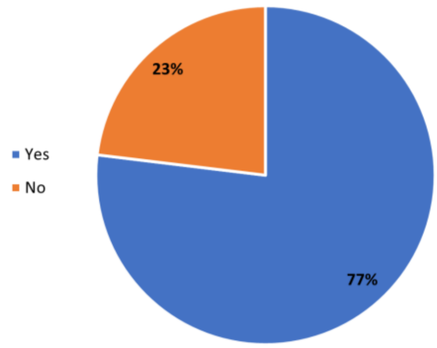

Figure 4.20- Difficulty in recruiting qualified personnel to operate with AM technology

Finally, related to how participating firms acquire knowledge about Additive Manufacturing technology, the most frequent answer is autonomous learning with 69% followed by third party training with 46% and lastly collaboration with academia with 31%. This information can be consulted in Figure 4.21.

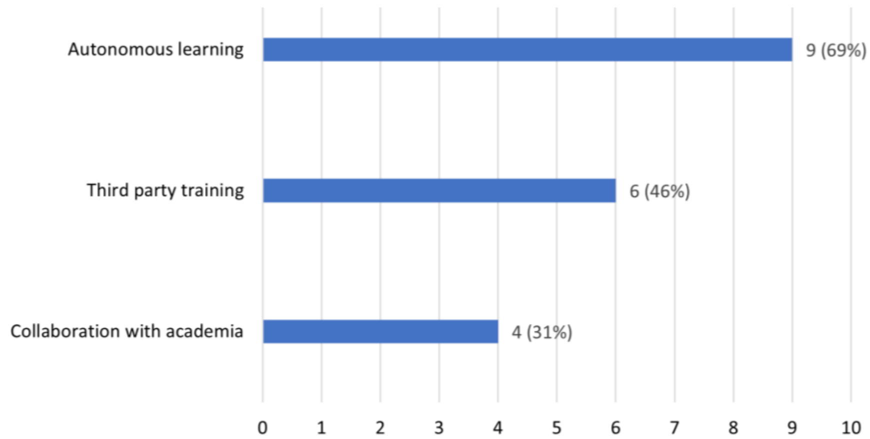

Figure 4.21- Forms of acquire knowledge about Additive Manufacturing technologies

Capital requirements. Firms were asked about investments made on Additive Manufacturing technologies in the last year, concerning software, equipment, and specialized workforce, either as training or employment. This is a topic of interest as one of the premises of the proposed model is that the use of AM will reduce upfront investments due its free forming nature. It should be noticed, however, that as most of the participating firms do not work exclusively with additive technologies this will probably not be the case. Figure 4.22 shows the investments made by the participating firms.

Two firms, corresponding to 15%, invested more than 100 000€ in the last year. Among those two firms is one of the participating firms that uses Additive Manufacturing technologies the most, namely FDM, SLS and SLA, which using industrial systems can cost more than 10 000€ each. The other firm is the one who uses Laser cladding for producing the final product, which has expensive set-up costs. Both firms employ 1 to 3 workers for additive production.

Most of the firms (62%) spent less than 10 000€ in the last year, which is in line with what has been already mentioned regarding the weight of production using Additive Manufacturing on the business and the purposes of use.

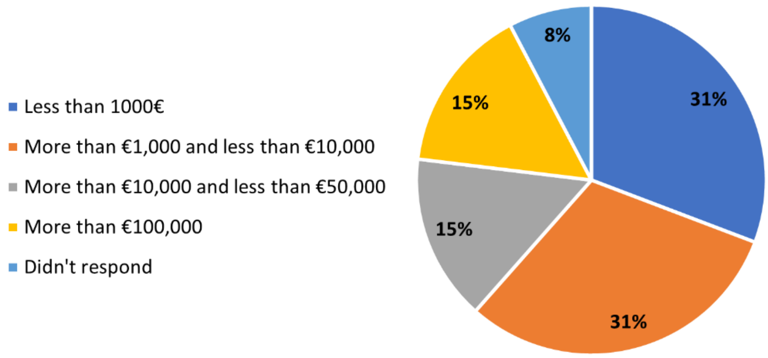

Figure 4.22- Investments made by the participating firms in Additive Manufacturing technologies in the last year

Intellectual Property Rights. Firms were asked about how they protect the knowledge held concerning Additive Manufacturing technology. Figure 4.23 shows which forms are used by firms.

As should be expected, most of the firms (77%) do not use any method available to protect the knowledge regarding Additive Manufacturing technologies. However, there are two firms that utilize patents (15%), where one also uses trade secrets plus confidentiality agreements while the other combines patents with utility models. Both firms carry out research activities.

Out of the four firms that produce final products with AM technologies, only one uses methods for knowledge protection, in particular trade secrets plus confidentiality agreements.

Still regarding this force, 3 statements were presented on which firms are asked to express an opinion about it. Table 2 specifies these statements and Figure 4.24 shows the frequency of response for each statement.

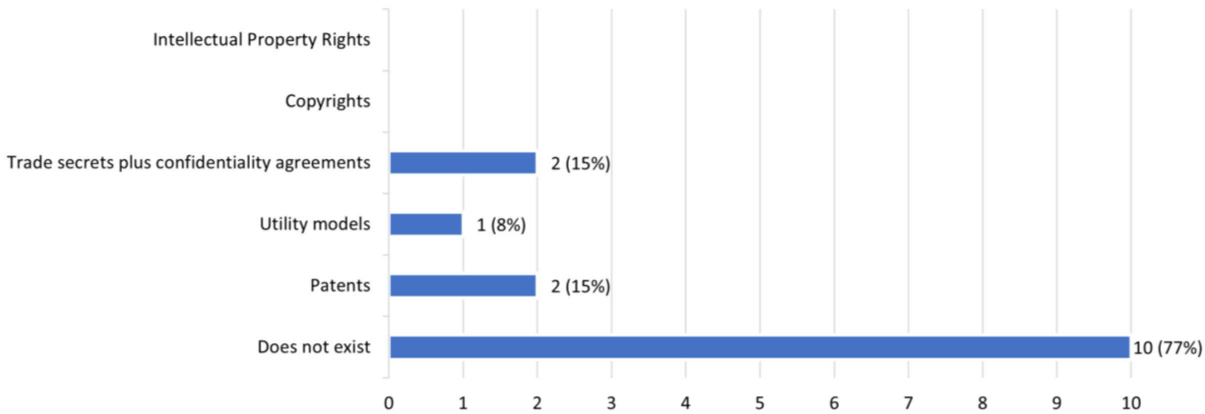

Figure 4.23- Methods for knowledge protection

Table 2- Statements regarding "Threat of new entrants"

Affirmation	Description
1	Established firms have the resources to fight the entry of new competitors.
2	The entry of new competitors requires large investments in equipment, hand-labor and/or R&D.
3	The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights).

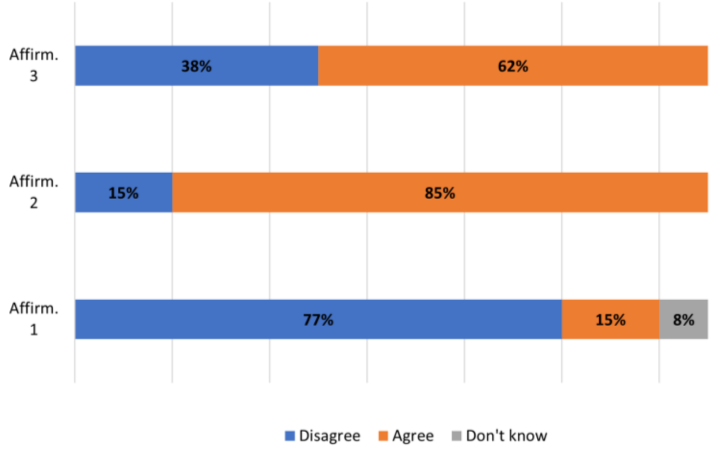

Figure 4.24- Frequency of response for each statement

According to Figure 4.24, most of the participating firms disagree that established firms detain the resources needed to prevent the entry of new competitors in the sector.

On one hand, regarding capital requirements almost everyone agrees that newcomers face high expenses to enter AM's market.

On the other, based on Figure 4.24, the participating firms seem to have conflicting opinions concerning the lack of a regulatory system. For some it makes it easier for newcomers to succeed, for others not so.

According to the proposed model, the factors that would influence Bargaining power of Customers are:

1) Extended User Responsibility (EUP)
2) Democratization of manufacturing
3) Globalization
4) Information

Extended User Responsibility. To understand the feasibility regarding the introduction of the EUP legislation, the participating firms were asked about the after-sales services offered. As it is intended to know if firms provide customers with the necessary information and support so that they have autonomy to repair their product if they wish so.

As Figure 4.25 shows, many of the participating firms offer support and assistance (54%) and customer service (46%). This happens as the law requires it. In other cases, it may be referent to supply contracts that deliver after-sales services. Although there are thirteen participating firms, only five (38%) offer repair services. Therefore, if customers could be able to repair their products without breaking warranties this could represent an opportunity for those firms that do not offer repair services but also for those that do. The reason why is that this could bring closer the producer and consumer, both benefiting from co-creation. On one hand, because customer would not need to depend on a manufacturer and on the other, the producer could beneficiate from customers' feedback.

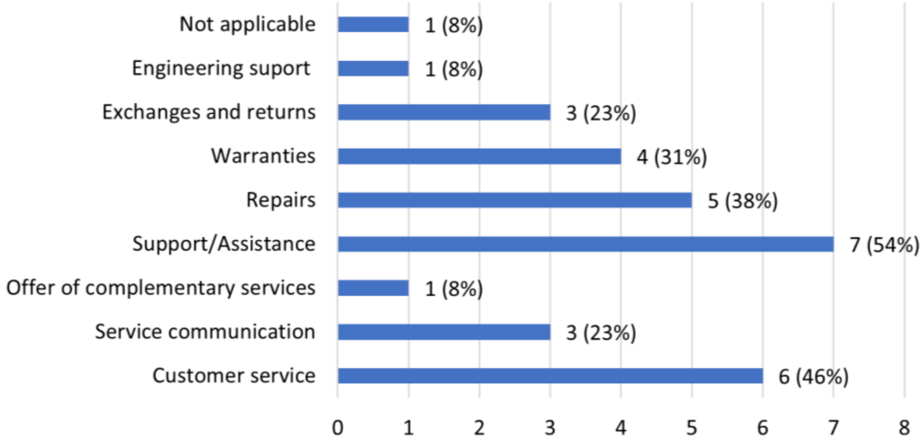

Figure 4.25- After-sales services offered

Democratization of manufacturing. As for the democratization of manufacturing the objective is to comprehend customers' role in manufacturing either as producer or simply as collaborator. For that firms were asked about their customers' contribution to product/service development. Figure 4.26 shows their responses to that. The top 3 areas where most of the firms confirm customers' contribution are design (69%), ideas generation (46%) and product testing (38%). This is in line with what was already mentioned regarding firms benefiting from customers' involvement. To conclude this topic of the democratization of manufacturing, firms were also asked to give their opinion regarding customers entering the market as producers – which is termed as "prosumerism".

As it is shown in Figure 4.27, there is no consensus about the fact that the easy access to production with AM technologies allows customers to enter the market as competitors. The reason why is considered that the access to AM production could be easy is because nowadays anyone who wants can easily have a 3D printer at home, as happened with the conventional printers.

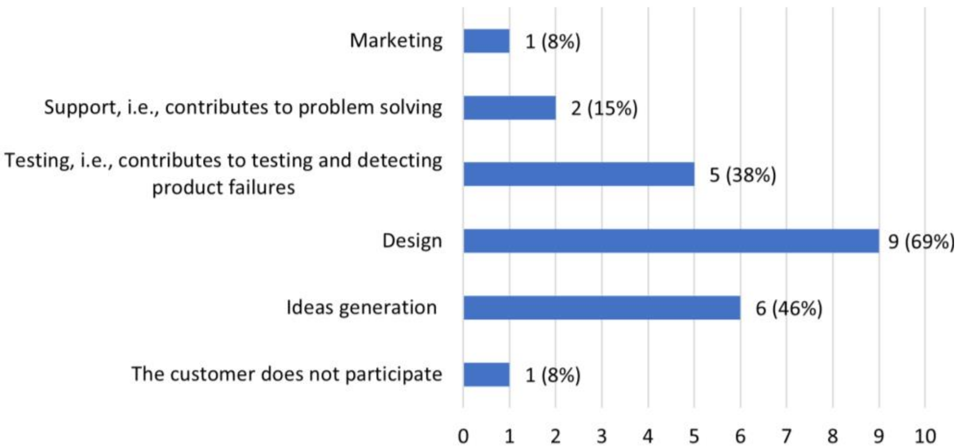

Figure 4.26- Customers contribution to product/service development

Table 3- Statement regarding "Bargaining power of customers"

Affirmation	Description
5	Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.

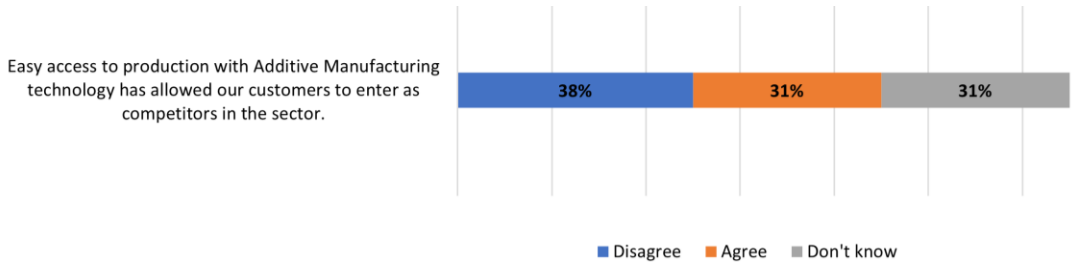

Figure 4.27- Firms' opinions regarding customers as competitors

Information and globalization. These two factors are analyzed together because the availability of information through non-face-to-face ways allows customers to buy globally.

Figure 4.28 shows the means that participating firms use to share information about their products/services with customers.

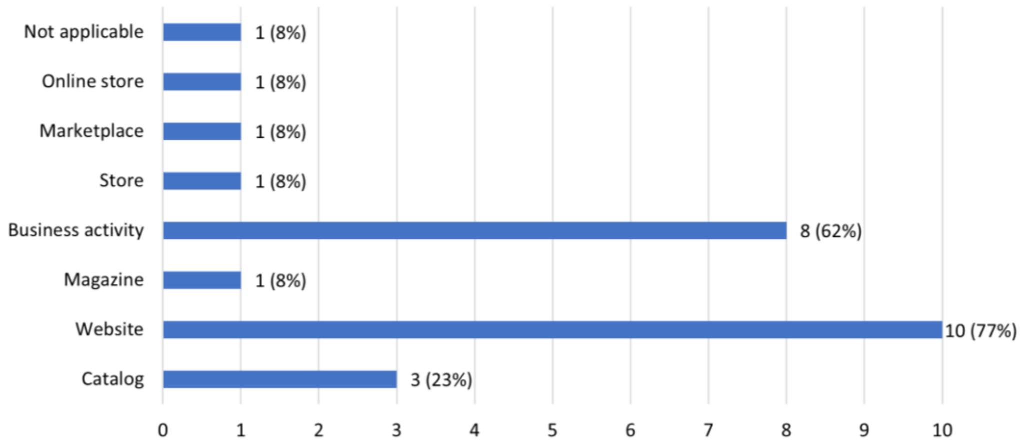

Figure 4.28- Means employed by firms to share information's about their products/service with customers

According to Figure 4.28, most of the participating firms share information regarding their products on websites (77%). This suggests that although these firms are in Portugal, customers buy from any part of the world, as their products' information is available for anyone who searches for it. Another mean that is also frequently used among these firms is business activity (62%).

As happened before, some statements were given for firms to express their opinion. Table 4 presents the statements in question.

Table 4- Statements regarding "Bargaining power of customers"

Affirmation	Description
4	The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.
6	Our customers have enough knowledge/information about the industry to assess the quality and value of products.
7	Our customers are mainly wholesalers and retailers with the power to influence the purchase of final consumers.

Figure 4.29 shows that there is no unanimity about AM affecting the bargaining power of the customers and many of the participating firms do not even express an opinion about it. However, concerning statement 6 most of the firms seem to agree with the fact that customers have enough knowledge/information to assess the quality and value of their products.

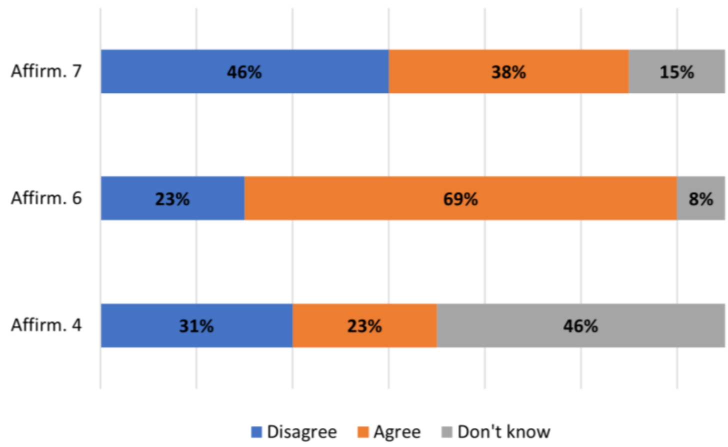

Figure 4.29- Frequency of response for each statement

Statement 7 allows to conclude that six firms (46%), out of thirteen, likely run their operations in B2C markets while five (38%) run their operations in B2B markets, where wholesalers and retailers have the power to influence the customers choices.

According to the proposed model factors that would influence Threat of Substitutes are:

1) Conventional Manufacturing
2) Swap 'n' go providers

To understand how these factors influence this force, firms were asked to give their opinion about some statements. Statement 8 to statement 10 are regarding threat of substitutes products broadly, while statement 11 is related to **conventional manufacturing** and statement 12 to the viability of **swap 'n' go providers** services. Table 5 presents the statements to be analyzed.

Table 5- Statements regarding "Threat of substitutes"

Affirmation	Description
8	The needs that our products meet can be met by products from other sectors.
9	There is considerable pressure for cheaper substitute products.
10	There are substitute products with a better price- performance.
11	The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.
12	Customers find it easy to use other firms instead of our after-sales service.

From Figure 4.30 is possible to conclude that there does not exist a clear consensus regarding substitutes products for theirs from other sectors. However, the opinion of most of the participating firms is that there are no products in other sectors able to satisfy the needs that theirs meet. This aspect is important as potential profit can be threatened. Also, this can show up as an opportunity for firms from other sectors, especially if the firms being threatened have no information about it.

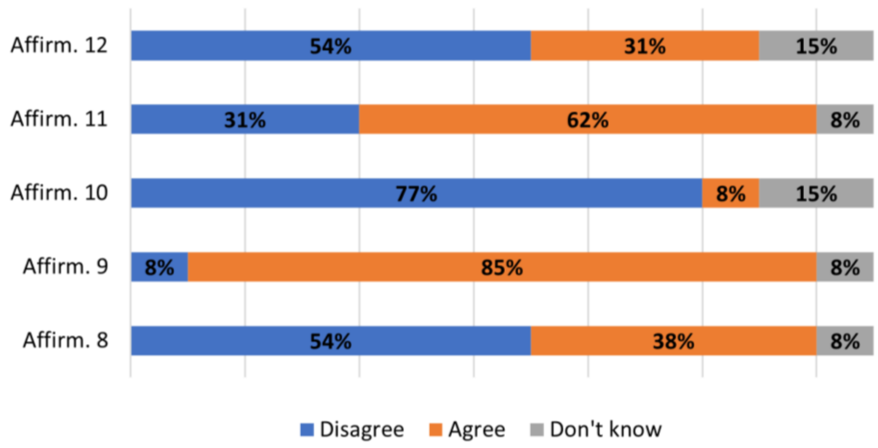

Figure 4.30- Frequency of response for each statement

As for pressure of cheap substitutes (statement 9), most of the participating firms show unanimity in their opinion. Still, most of the firms disagree that exist substitute products with better price-performance. From the opinions expressed regarding statement 9 and statement 10 it is possible to conclude that although there is a considerable pressure for substitutes in the market, those products do not seem to constitute a threat for many of the participating firms.

Regarding statement 11 most of the firms agree that AM technology does not add value for the firm, while 31% of the firms disagree. Of those 31%, which corresponds to four firms, one produces final products with AM technologies, specifically Laser cladding. This opinion is reasonable as Laser cladding offers lower heat distortion, reduced dilation and low porosity levels in comparison with other methods.

As for statement 12 most of the participating firms disagree that customers find it easier to resort to other firms for repairs or upgrades instead of their after-sales service.

According to the proposed model factors that would influence Bargaining power of Suppliers force are:

1) Supply chain decentralization
2) Shortening of supply chains
3) Democratization of manufacturing
4) Vertical integration

Decentralization and shortening of supply chains. These two factors are analyzed together as one influence the other, i.e., only if the firm has taken efforts to supply chain decentralization occur can feel effects on supply chain length.

For that, firms were asked about to what extent are their suppliers integrated in the processes of the organization. Figure 4.31 shows the possibilities and frequency of each.

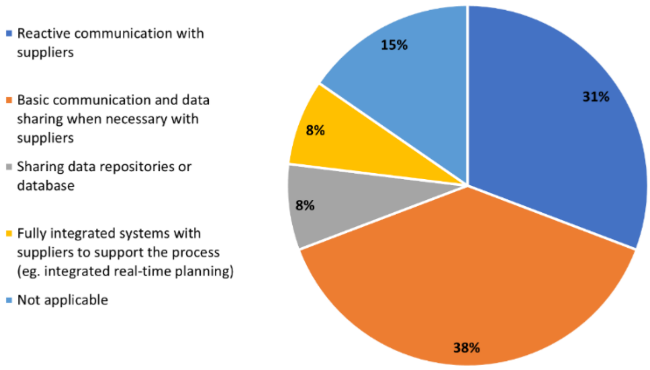

Figure 4.31- Supplier’s integration in firms' operation

The only firm that acknowledges to be fully integrated with the suppliers is the same that reports on Figure 4.16 that benefits from supply chain simplification as result of Additive Manufacturing technology. This makes sense because it allows the firm to decentralize decisions to their suppliers, instead of having resources exclusively allocated for that.

Most of the participating firms (69%) has reactive communication or only shares data when asked for.

Vertical integration. To test the feasibility of vertical integration, firms were asked to express an opinion about the ability of the suppliers to align themselves with their productive process. The statement used to assess it is shown in Table 6.

Table 6- Statement regarding suppliers' ability to align with firms' production process

Affirmation	Description
13	Suppliers find it easy to align themselves with our production process.

Most of the participating firms agree that for their suppliers would be easy to align with their production process, as shown in Figure 4.32.

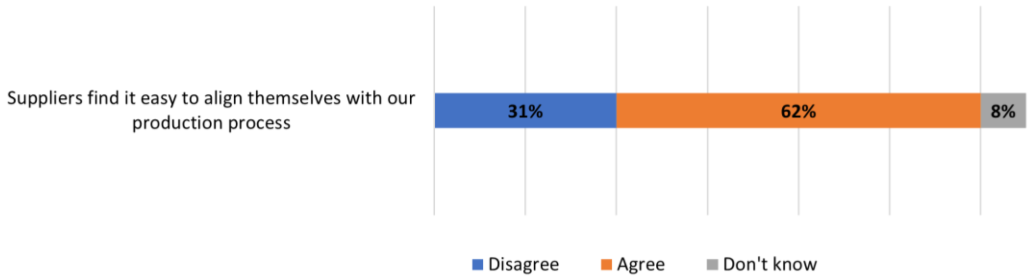

Figure 4.32- Firms' opinions regarding suppliers' vertical integration

To evaluate bargaining power of the suppliers, in general, firms were asked to give their opinion regarding some statements. Table 7 presents the statements.

Table 7- Statements regarding "Bargaining power of suppliers"

Affirmation	Description
14	Suppliers find it easy to raise prices or reduce product quality.
15	There are a small number of suppliers that respond to a large proportion of the sector's raw materials.
16	Competition is strongly influenced by the bargaining power of suppliers.
17	Firms operating in this sector can easily change their supplier.

Most of the participating firms disagree that is easy for their suppliers to raise prices or reduce product quality (Figure 4.33). However, most of the firms agree that there is a small number of suppliers to respond to the needs of raw materials of their sector. As for competition, the participating firms agree that suppliers' bargaining power strongly influences it.

Although there is a consensus regarding a small group of suppliers providing the sector needs, most of the firms also agree that it does not constrain them when it comes to change suppliers.

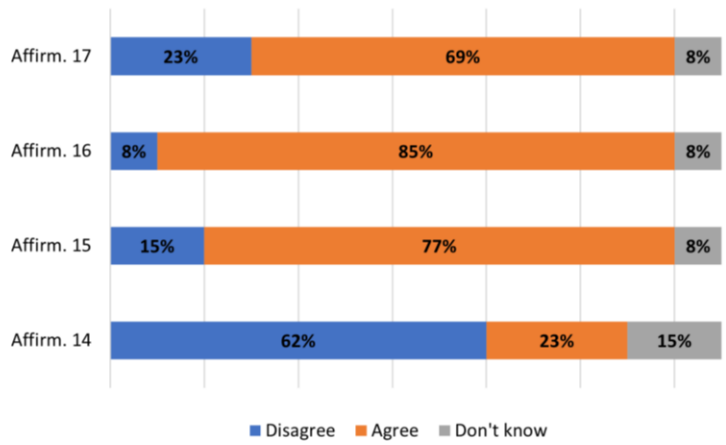

Figure 4.33- Frequency of response for each statement

According to the proposed model factors that would influence Rivalry among the existing competitors force are:

1) Rivalry as a new sector
2) More access to information and knowledge
3) 3DP Centers/ 3DP Desktops
4) Growing awareness by stakeholders
5) Globalization
6) IPR

To understand how these factors influence this force, firms were asked to give their opinion about some statements. Table 8 presents the statements.

Table 8- Statements regarding "Rivalry among the existing competitors"

Affirmation	Description
18	The competitiveness between firms that use Additive Manufacturing is intense.
19	There is a wide variety of competitors that use the Additive Manufacturing technology.
20	The use of Additive Manufacturing technology allows firms in this sector to serve different markets.
21	Changes in our strategy have noticeable effects on competing firms.
22	The lack of a regulatory system for copyright presents an opportunity for firms.
23	Technological advances allow better access to knowledge of Additive Manufacturing technologies.

According to Figure 4.34 most of the participating firms agree that competition between AM users is intense. This can be due to the rising rates that the adoption of AM technologies has undergone in the last few decades. The conclusions for statement 18 are also true for statement 19 as they both are consequence of the same, plus the advances and improvements achieved in recent years.

As regard to statement 20, most of the participating firms agree that the use of AM technology facilitates firms to serve multiple sectors. Thus, this allows to assert that the use of AM technology is taking rivalry to a different degree of intensity, as firms do not compete only with firms within the same sector, but with all the ones who serve the same markets.

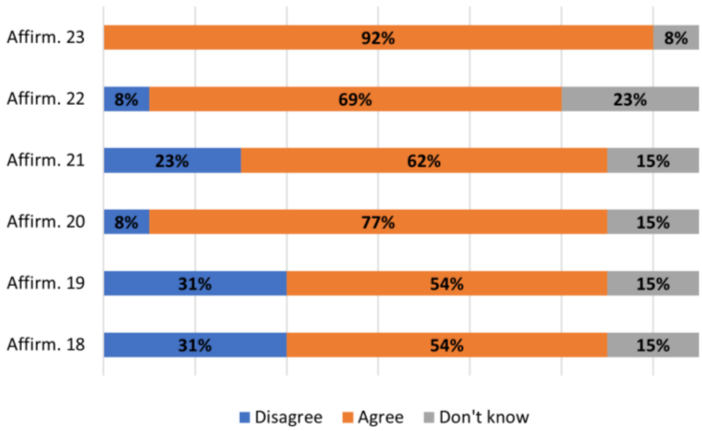

Figure 4.34- Frequency of response for each statement

It is possible to conclude from Figure 4.34 that most of the participating firms act in sectors where changes in their strategy affect the competing firms (statement 21). Three firms disagree with this statement. Among those, two act in sector G, corresponding to Wholesale and Retail Trade: Cars and Motorcycles vehicle repair. The other firm, even though it acts in sector C, corresponding to Manufacturing Industries – as most of the ones who agree – has less than 5% of market share.

Considering statement 22, most firms agree that the lack of a regulatory system for copyright represents as an opportunity for firms.

Lastly all the firms, except one that does not express an opinion, agree that technological advances provide firms better access to knowledge about AM technologies (statement 23).

4.2 Analyzing Sector C: Manufacturing Industries

In this section, is analyzed the concordance of the participating firms from sector C regarding the statements, already presented, concerning Porter's Five Forces model adaptation (Porter, 1979).

For this assessment is used the GRA method – that is described in Data Analysis Methods section – to measure the concordance of an answer to a reference value. The values presented in the next figures are mean values for the sector. In annex A.3 Grey Relational Analysis Sector C: Manufacturing Industries is possible to consult in detail how those values are obtained.

According to Table 9 in this sector most firms disagree that established firms have the resources to fight the entry of new competitors. A possible explanation for this is that all the firms that are part of this sector only make use of Additive Manufacturing technology to support or enhance their performance. These firms show moderate agreement on the need for high capital requirements for the entry of new competitors and low agreement on the lack of a regulatory system as a facilitator of success for newcomers.

Table 9- Concordance to the statements regarding "Threat of new entrants" force

Affirmation	Description	Concordance	Label
1	Established firms have the resources to fight the entry of new competitors.	0,437	Disagreement
2	The entry of new competitors requires large investments in equipment, hand- labor and/or R&D.	0,759	Moderate agreement
3	The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights).	0,568	Low agreement

Regarding the bargaining power of customers Table 10 shows that most of the participating firms disagree that AM technologies have empowered "prosumerism" and customers' bargaining power. Yet, most of these firms agree – although with a low agreement – that their customers have sufficient knowledge and information to assess the quality and value of their products.

Table 10- Concordance to the statements regarding "Bargaining power of customers" force

Affirmation	Description	Concordance	Label
4	The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.	0,497	Disagreement
5	Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.	0,459	Disagreement
6	Our customers have enough knowledge/information about the industry to assess the quality and value of products.	0,679	Low agreement

According to Table 11, most of the firms from this sector disagree that their customers find it easy to resort to other firms instead of their after-sales services. This can be due to fact that many of these firms provide reparation services, exchanges and returns or warranties for their products. On the other hand, they express a low concordance regarding the existence of substitute products to theirs from other sectors.

They also agree, with low concordance, that AM technology do not add value to firms as a process to produce standard products.

Table 11- Concordance to the statements regarding "Threat of substitutes" force

Affirmation	Description	Concordance	Label
8	The needs that our products meet can be met by products from other sectors.	0,569	Low agreement
11	The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.	0,564	Low agreement
12	Customers find it easy to use other firms instead of our after-sales service.	0,478	Disagreement

Table 12 shows that most of the firms from this sector disagree with statement 17.

Only for this statement, the disagreement is not regarding the statement itself but rather to the reference value. In this case, the reference value set is 1 – which corresponds to Totally disagree. This happened as one of the research hypotheses is that the bargaining power of the suppliers is positively influenced by the introduction of AM technology, meaning that suppliers gain more leverage in negotiation. The choice of this reference value was so that the conclusions were in accordance with the research hypothesis, which would not be possible if it is considered that firms change suppliers easily. On the other hand, firms agree, with low concordance, that suppliers have the power to raise prices or reduce product quality. Regarding the remaining statements for this force, the agreement level fits the low concordance.

Table 12- Concordance to the statements regarding "Bargaining power of suppliers" force

Affirmation	Description	Concordance	Label
13	Suppliers find it easy to align themselves with our production process.	0,557	Low agreement
14	Suppliers find it easy to raise prices or reduce product quality.	0,502	Low agreement
15	There are a small number of suppliers that respond to a large proportion of the sector's raw materials.	0,629	Low agreement
16	Competition is strongly influenced by the bargaining power of suppliers.	0,679	Low agreement
17	Firms operating in this sector can easily change their supplier.	0,438	Disagreement

Lastly, regarding to the factors that influence rivalry – Table 13– in general firms show agreement, even if low. This means that firms consider that AM introduction affects:

1) Competitiveness, as most agree that is intense between user firms;
2) The number of users, as most agree that currently there are several competitors using these technologies;
3) The markets where firms operate, as they agree that this technology allows to serve different markets;
4) Strategy, as changes in one firm have noticeable effects on the competitors;
5) New opportunities, as they all agree that the lack of a regulatory system for copyright can present as an opportunity for firms.

Table 13- Concordance to the statements regarding "Rivalry among the existing competitors" force

Affirmation	Description	Concordance	Label
18	The competitiveness between firms that use Additive Manufacturing is intense.	0,527	Low agreement
19	There is a wide variety of competitors that use the Additive Manufacturing technology.	0,527	Low agreement
20	The use of Additive Manufacturing technology allows firms in this sector to serve different markets.	0,690	Low agreement
21	Changes in our strategy have noticeable effects on competing firms.	0,619	Low agreement
22	The lack of a regulatory system for copyright presents an opportunity for firms.	0,657	Low agreement

Table 14 summarizes the conclusions regarding this analysis.

Table 14- Summary of the conclusions sector C

Conclusions	Description
Concordance	• This sector acknowledges the importance capital requirements and IPR can have on Threat of new entrants. • Customers knowledge about the industry requirements influence bargaining power of customers. • Substitute products from other industries and AM as method to produce standard products are influencing factor of Threat of substitutes. • Vertical integration by suppliers is a reality. This increases supplier bargaining power, that in turn strongly influence competition. However, firms can easily change their supplier even if a small group of suppliers exist to respond to sector needs. • Exists a wide range of AM users and the competition between them is intense. AM allows firms to be more competitive, by operating in multiple markets. The lack of a regulatory system for copyright and technological advances are opportunities that allows firms to benefit from AM technology.
Disagreement	• There is no consensus about established firms detaining newcomers, evidences that AM technology increased bargaining power of customers and customers recurring to other firms for after-sales services.

4.3 Analyzing Sector G: Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair

In this section is analyzed the concordance of the participating firms from sector G regarding the statements, already presented, concerning Porter's Five Forces model adaptation (Porter, 1979).

For this assessment is used GRA method, as did in the previous section. The values that are presented in the next figures are mean values for the sector. In annex A.4 Grey Relational Analysis Sector G: Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair is possible to consult in detail how those values are obtained. As regard to threat of new entrants, most of the firms from sector G disagree that established firms have the resources to fight the entry of new competitors. These firms use AM technologies to produce final products, still they don't think that established firms could detain newcomers.

Nevertheless, sector G shows low agreement on the need for high capital requirements for the entry of new competitors and on the lack of a regulatory system – as a facilitator of success for newcomers. Table 15 shows the information that allows to conclude the aforementioned.

Table 15- Concordance to the statements regarding "Threat of new entrants" force

Affirmation	Description	Concordance	Label
1	Established firms have the resources to fight the entry of new competitors.	0,486	Disagreement
2	The entry of new competitors requires large investments in equipment, hand- labor and/or R&D.	0,543	Low agreement
3	The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to IP rights).	0,676	Low agreement

According to Table 16, in general, these firms disagree that: (1) "prosumerism" is a factor that affects the bargaining power of the customers, (2) customers have enough knowledge and information to assess the quality and value of their products. Still, this sector shows agreement, even if low, regarding customers benefiting from higher bargaining power due to AM technology introduction.

Table 16- Concordance to the statements regarding "Bargaining power of customers" force

Affirmation	Description	Concordance	Label
4	The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.	0,514	Low agreement
5	Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.	0,454	Disagreement
6	Our customers have enough knowledge/information about the industry to assess the quality and value of products.	0,486	Disagreement

Concerning Table 17, substitute products from other sectors do not constitute a threat for most of the firms from sector G, as they disagree with statement 8. On contrary, they all agree that the use of AM technology for producing standard products do not constitute an added value activity from firms. Thus, for statement 11 firms show a moderate accordance. Regarding statement 12 most of the firms from sector G agree, with low agreement, that customers find it easy to resort to other firms instead of their after-sales service. This can be due to the fact that of these firms, only one offers repair services.

Table 17- Concordance to the statements regarding "Threat of substitutes" force

Affirmation	Description	Concordance	Label
8	The needs that our products meet can be met by products from other sectors.	0,454	Disagreement
11	The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.	0,6733	Low agreement
12	Customers find it easy to use other firms instead of our after-sales service.	0,453	Disagreement

As for the ability of suppliers to align themselves with the productive process of the firms and easily raise prices or reduce products quality, firms from sector G disagree as is shown in Table 18.

On the other hand, most of these firms agree, with low concordance, that there is a small number of suppliers who responds to a large portion of the sector's raw materials and with statement 17. As previosly mentioned about statement 17, the agreement is not regarding the statement itself but rather to the reference value. Thus, is possible to conclude that most of these firms disagree that is easy to change suppliers. Lastly, all firms from sector G agree that the bargaining power of the suppliers strongly influences competition. The agreement with this statement is moderate.

Table 18- Concordance to the statements regarding "Bargaining power of suppliers" force

Affirmation	Description	Concordance	Label
13	Suppliers find it easy to align themselves with our production process.	0,454	Disagreement
14	Suppliers find it easy to raise prices or reduce product quality.	0,397	Disagreement
15	There are a small number of suppliers that respond to a large proportion of the sector's raw materials.	0,543	Low agreement
16	Competition is strongly influenced by the bargaining power of suppliers.	0,733	Moderate agreement
17	Firms operating in this sector can easily change their supplier.	0,543	Low agreement

As Table 19 and Table 20 depict, firms from sector G in general agree, with agreement varying from low to moderate, that the presented factors influence rivalry. This means that the firms consider that AM introduction affects:

1) Competitiveness, as most agree that is intense between user firms;
2) The number of users, as most agree that currently there are several competitors using these technologies;
3) The markets where firms operate, as all agree that this technology allowed to serve different markets;
4) Strategy, as changes in a firm have noticeable effects on the competitors;
5) New opportunities, as most agree that the lack of a regulatory system for copyright can present as an opportunity for firms.

Table 19- Concordance to the statements regarding "Rivalry among the existent competitors" force

Affirmation	Description	Concordance	Label
18	The competitiveness between firms that use Additive Manufacturing is intense.	0,543	Low agreement
19	There is a wide variety of competitors that use the Additive Manufacturing technology.	0,543	Low agreement
20	The use of Additive Manufacturing technology allows firms in this sector to serve different markets.	0,733	Moderate agreement
21	Changes in our strategy have noticeable effects on competing firms.	0,619	Low agreement
22	The lack of a regulatory system for copyright presents an opportunity for firms.	0,810	Moderate agreement

Table 20 summarizes the conclusions regarding this analysis.

Table 20- Summary of the conclusions sector G

Conclusions	Description
Concordance	• Firms from this sector acknowledge the importance capital requirements and IPR can have on Threat of new entrants. • The introduction of AM technology increased bargaining power of customers. • For this sector customers find it easy to recur to other firms for after-sales services. AM as method to produce standard products can expose firms to substitute threats. • Suppliers bargaining power strongly influence competition. However, firms can easily change their supplier even if a small group of suppliers exist to respond to sector needs. • Exists a wide range of AM users and the competition between them is intense. AM allows firms to be more competitive, by operating in multiple markets. The lack of a regulatory system for copyright and technological advances are opportunities that allows firms to benefit from AM technology.
Disagreement	• There is no consensus regarding established firms having the resources needed to detain newcomers and that customers possess sufficient knowledge to assess industry requirements. Substitute products from other industries and vertical integration by suppliers are not a reality for this sector.

4.4 Analyzing Sector M: Consulting, Scientific, Technical and Similar Activities

In this section is analyzed the concordance of the participating firm from sector M regarding the statements, already presented, concerning Porter's Five Forces model adaptation (Porter, 1979).

For this assessment is used GRA method as did in the previous sections. The values that are presented in the next figures correspond to real values as this sector is composed only by one firm. In annex A.5 Grey Relational Analysis Sector M: Consulting, Scientific, Technical and Similar Activities is possible to consult in detail how those values are obtained.

Table 21 shows that this firm has low agreement regarding the need for high capital requirements by newcomers as well as that the lack of a regulatory system facilitates the success of new competitors. Regarding statement 1 the opinion given is counted as a non-answer.

Table 21- Concordance to the statements regarding "Threat of new entrants" force

Affirmation	Description	Concordance	Label
1	Established firms have the resources to fight the entry of new competitors.		
2	The entry of new competitors requires large investments in equipment, hand- labor and/or R&D.	0,600	Low agreement
3	The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights).	0,600	Low agreement

Regarding the factors that influence the bargaining power of the customers, this firm agrees that the introduction of AM technology gives high bargaining power to customers as it also allows for customers to enter as competitors. This information can be seen in Table 22.

It is noteworthy to add that this firm uses AM technologies to produce final products.

Table 22- Concordance to the statements regarding "Bargaining power of customers" force

Affirmation	Description	Concordance	Label
4	The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.		
5	Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.	0,600	Low agreement
6	Our customers have enough knowledge/information about the industry to assess the quality and value of products.	0,600	Low agreement

About statement 8 and statement 11, this firm agrees that there are substitutes for its products from other sectors and that the use of AM technology to produce standard products do not constitute an added value activity for the firm.

As for statement 12, this firm disagrees that customers find it easier to resort to other firms for after-sales services. A potential reason for this opinion can be the fact that this firm offers repair services. Table 23 schematizes the information above.

Table 23- Concordance to the statements regarding "Threat of substitutes" force

Affirmation	Description	Concordance	Label
8	The needs that our products meet can be met by products from other sectors.	0,600	Low agreement
11	The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.	0,600	Low agreement
12	Customers find it easy to use other firms instead of our after-sales service.	0,429	Disagreement

This firm agrees, with low concordance, that suppliers could easily align themselves with the production process. On the other hand, this firm disagrees that suppliers can easily raise prices or reduce product quality.

Regarding, statement 15 and statement 16 this firm shows a strong concordance. They agree that there is a small number of suppliers to respond to the needs of the sector and that their bargaining power strongly influence the competition of the sector.

The disagreement in relation to statement 17, as previously stated, is not regarding the statement itself but rather to the reference value, which means that for this firm, firms operating in sector G can easily change suppliers. This information can be seen in Table 24.

Table 24- Concordance to the statements regarding "Bargaining power of suppliers" force

Affirmation	Description	Concordance	Label
13	Suppliers find it easy to align themselves with our production process.	0,600	Low agreement
14	Suppliers find it easy to raise prices or reduce product quality.	0,429	Disagreement
15	There are a small number of suppliers that respond to a large proportion of the sector's raw materials.	1,000	Strong agreement
16	Competition is strongly influenced by the bargaining power of suppliers.	1,000	Strong agreement
17	Firms operating in this sector can easily change their supplier.	0,333	Disagreement

Lastly, as Table 25 shows, this firm shows low agreement regarding the factors concerning the rivalry among the existent competitors.

Table 25- Concordance to the statements regarding "Rivalry among the existent competitors" force

Affirmation	Description	Concordance	Label
18	The competitiveness between firms that use Additive Manufacturing is intense.	0,600	Low agreement
19	There is a wide variety of competitors that use the Additive Manufacturing technology.	0,600	Low agreement
20	The use of Additive Manufacturing technology allows firms in this sector to serve different markets.	0,600	Low agreement
21	Changes in our strategy have noticeable effects on competing firms.	0,600	Low agreement
22	The lack of a regulatory system for copyright presents an opportunity for firms.	0,600	Low agreement

Table 26 summarizes the conclusions regarding this analysis.

Table 26- Summary of the conclusions sector M

Conclusions	Description
Concordance	• Firms from this sector acknowledge the importance capital requirements and IPR can have on Threat of new entrants. • Customers knowledge about the industry requirements influence bargaining power of customers. On the other hand, the easy access to AM technology customers entered as competitors in the sector. • Substitute products from other industries and AM as method to produce standard products are influencing factor of Threat of substitutes. • Vertical integration by suppliers is a reality. This increases supplier bargaining power, that in turn strongly influence competition. However, exists a small group of suppliers to respond to sector needs. This sector acknowledge that is not easy to change suppliers. • Exists a wide range of AM users and the competition between them is intense. AM allows firms to be more competitive, by operating in multiple markets. The lack of a regulatory system for copyright and technological advances are opportunities that allows firms to benefit from AM technology.
Disagreement	• There is no opinion about established firms having the resources to detain newcomers or increased bargaining power of customers. There is no consensus regarding customers recurring to other firms for after-sales services or suppliers easily raising prices/ reduce product quality.

4.5 Comparing Sector C, G and M

Concerning the statement "Established firms have the resources to fight the entry of new competitors", firms from sector C and G show disagreement. However, for statement "The entry of new competitors requires large investments in equipment, hand-labor and/or R&D" and "The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights)" all sectors seem to be consensual regarding their agreement with these statements.

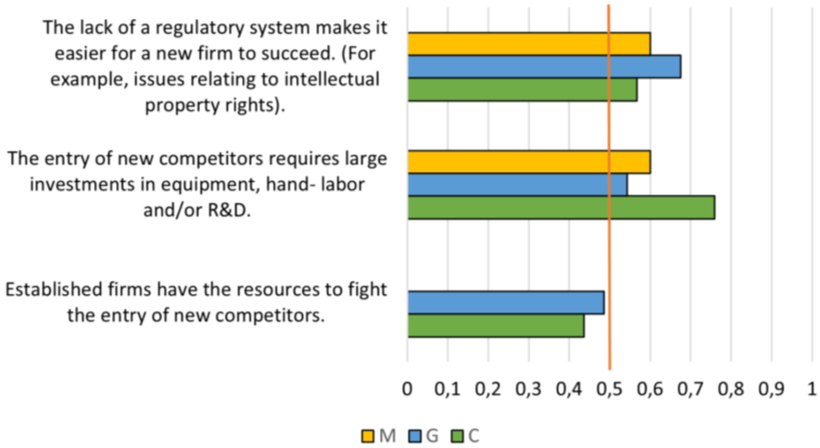

Figure 4.35- Concordance of the sectors to the statements regarding "Threat of new entrants" force

As for the statement "The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out", firms from sector C disagree while firms from sector G agree.

Regarding the statement "Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector", only sector M agrees that customers can get advantage from AM technologies and enter as competitors in the sector.

Lastly for the statement "Our customers have enough knowledge/information about the industry to assess the quality and value of the products", sector C and M recognize that in the sector they operate, customers have sufficient information and knowledge about the industry to assess the quality and value of their products.

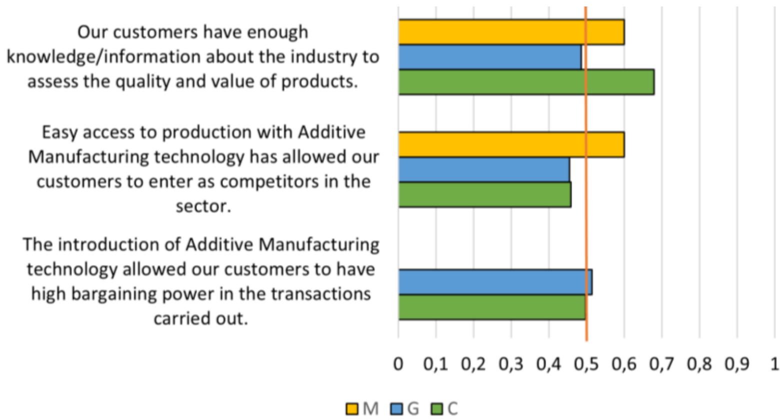

Figure 4.36- Concordance of the sectors to the statements regarding "Bargaining power of customers" force

For the statement "The needs that our products meet can be met by products from other sectors", both sector C and M agree with existence of substitute products for theirs from other sectors, while sector G disagrees with that.

As for the use of AM to produce standard products, all the sectors agree that it does not add value for firms. Finally, sector G is the only sector under study that shows concordance regarding the statement "Customers find it easy to use other firms instead of our after-sales service", which corresponds to customers' propensity to resort to other firms instead of their after-sales services.

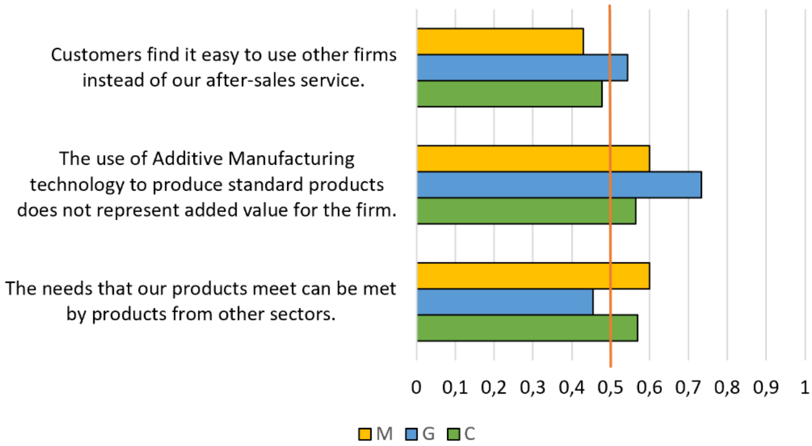

Figure 4.37- Concordance of the sectors to the statements regarding "Threat of substitutes" force

As for suppliers' ability to align themselves with the productive process of the firms, both sector C and M agree that suppliers find it easy. Regarding the statement "Suppliers find it easy to raise prices or reduce product quality", sector G and M disagree with suppliers' control to raise prices or reduce product quality unexpectedly. Concerning the statement "There are a small number of suppliers that respond to a large proportion of the sector's raw materials" and "Competition is strongly influenced by the bargaining power of suppliers", all sectors agree, particularly sector G that has a strong concordance.

For the statement "Firms operating in this sector can easily change their supplier", only sector G agrees that it is not easy for firms to change suppliers.

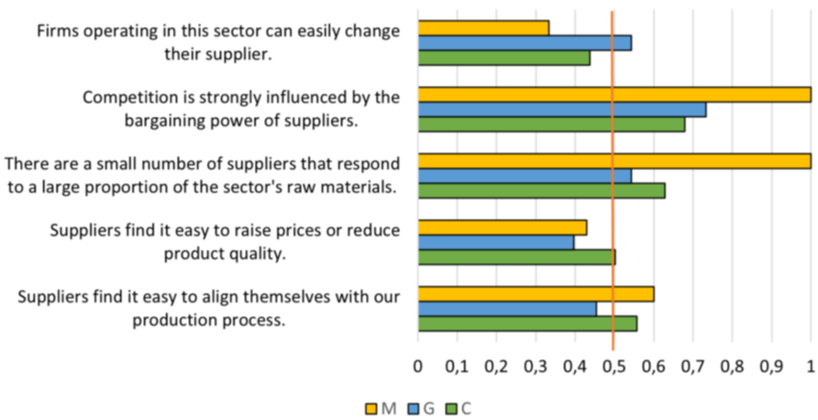

Figure 4.38- Concordance of the sectors to the statements regarding "Bargaining power of suppliers" force

According to Figure 4.39, there is a consensus among the sectors regarding the factors that influence the rivalry between competitors.

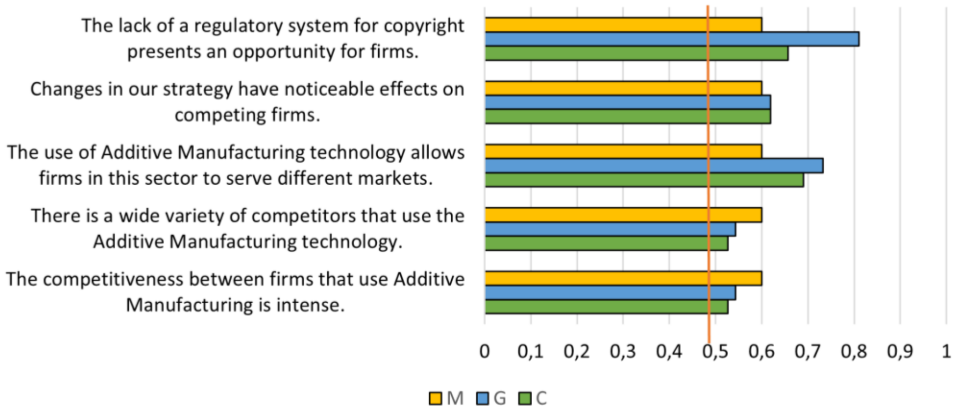

Figure 4.39- Concordance of the sectors to the statements regarding "Rivalry among the existing competitors" force

5
Conclusions and Final Considerations

The present dissertation shows that organizations can benefit from AM technology, even if there are some barriers to overcome in order not to miss this opportunity. AM as a new form of production will directly impact the existent manufacturing models as well as enhance new types of business. Hereupon it is important not only to study the economic aspects of this technology, such as the economic viability of the production, but also to focus on the changes that businesses will suffer.

As AM offers a range of possibilities, it is crucial that organizations recognize that their strategy plan of action is as influencing as the inherent shaping forces of their industry. The fact that AM is still in maturing phase requires more research to fully understand the impacts this technology will have on business models, which is the main goal of this work. The key issue in this case then concerns with the ability to effectively manage the knowledge the organizations hold so that they can extract its full potential, which ultimately leads to a reinforcement of the firm's economic position in the market. Hence, a well conducted structural analysis of the industry allows firms to understand the dynamics inherent to the industry, revealing that firms should not enter in fights over market share, but instead understand where and how they can add value for that industry.

The objectives proposed to be achieved with this research were the analysis of the impact of Additive Manufacturing technology on firms' business strategy and the study of Additive Manufacturing technology integration on Portuguese firms. Regarding these objectives, it can be stated that the first was achieved through the conceptualization of a structural analysis model adapted from Porter's Five Forces model to AM industry. The latter was not fully achieved, as the sample size did not allow to broadly characterize the AM technology integration on Portuguese firms, but rather for the firms in analysis.

The literature review conducted supports the formulation of the proposed model. This model reflects that both customers and suppliers will see their bargaining power increased, and rivalry tensions will be strengthened with the introduction of Additive Manufacturing technology. Regarding the threat of substitutes and the threat of new entrants, it will depend on the industry as economic feasibility and capital requirement are limiting factors. The research hypotheses are then extracted from these premises and are later verified through the questionnaire.

The participating firms mostly corroborate hypothesis H1: "Additive Manufacturing positively influences threat of new entrants". To test this hypothesis were given three statements linking retaliation from incumbent firms, capital requirements and regulatory systems to measure the height of entry barriers. From the sectors analysis it is possible to conclude that the participating firms do not expect retaliation against newcomers, which tends to lower entry barriers. Additionally, the participating firms agree that to enter the AM market they face high capital investments, however the firms that produce final products with AM technologies, corresponding to sector G (Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair) and sector M (Consulting, Scientific, Technical and Similar Activities), express low agreement with this statement. A possible explanation for this comes from the fact that most of these firms use these technologies as complementing tools and the expenses they need to incur are too high for this purpose. Regarding sectors' regulation, the firms generally agree that the lack of a regulatory system helps newcomers to succeed, which again lowers the entry barriers. Hagel et al. (2015) also corroborates that the use of AM lowers entry barriers due to: (1) Reduced capital investments (2) Accessible tools and collaboration and (3) Sector's regulation. Besides, they also endorse that customer increasing bargaining power is opening doors for niche markets to appear. Consequently, this makes it easier for new entrants to establish themselves.

Concerning H2: "Additive Manufacturing positively influences bargaining power of customers", there is no consensus around customers gaining more bargaining power, as only the firms who work as service providers express explicitly that the introduction of AM empowers their customers' bargaining power. However, Hagel et al. (2015) argues that the shifts traditional manufacturing has been experiencing have resulted in customers becoming more involved in production, through partnerships, and in the acquisition process, through e-commerce. Additionally, Sonny (2020) defends that with the implementation of Industry 4.0, large amounts of product usage data become available, giving more leverage power to customers in negotiation.

With respect to H3: "Additive Manufacturing does not influence threat of substitutes", most of the participating firms believe that the use of AM technologies to produce standard products does not constitute added value for them. Still, it is noteworthy that four of the participating firms produce final products with AM, where three of them constitute sector G and it is in this sector that exist a higher level of concordance. Reinforcing that AM is not the most suitable method for producing standardized products, Ding et al. (2021) affirms that the impacts of unplanned variations in product properties, which directly influence the economics of the processes, are not yet fully understood in the case of AM. This is a major reason why AM is still considered a cost-effective method only to manufacture small volumes, rather than medium/large volumes.

Regarding H4: "Additive Manufacturing positively influences bargaining power of suppliers", the participating firms express that, with the introduction of AM, suppliers strongly influence competition and that there exists a small number of suppliers responding to the needs of the sector. Also, most of the firms state that it is easy for their suppliers to align themselves with the firms' production processes. This can be seen as a consequence of Industry 4.0 which directly affects "technological suppliers, additive manufacturing technical firms and technological service providers" (Godina et al., 2020).

Concerning H5: "Additive Manufacturing increases the rivalry among the existent competitors", the participating firms agree that competition in AM market is intense as a wide range of competitors make use of AM technologies. The fact that many organizations exploit these technologies to conduct business is a consequence of the flexibility AM technologies provide when producing, allowing firms to serve different markets at once. Furthermore, it is believed that with AM consolidation it will be possible for firms to take advantage of much improved interoperability which will result in higher competition (Petch, 2022).

After analyzing all the information collected, it is possible to conclude that all the participating firms, except one, fit in the incremental stream of development as regard to Additive Manufacturing technology, more precisely, on closed-incremental stream. In this stream, AM technologies appear as a complementing tool and its equipment a natural part of the manufacturing process.

In sum, the proposed model can be refined according to the respondents' input. For the "Threat of new entrants", the factors that influence this force are the high capital requirements needed as well as IPR that are portrayed by the lack of a regulatory system. On top of that, the democratization of manufacturing opened new doors, and the lack of a regulatory system can help take advantage of that. Even though capital requirements are high and new entrants are likely to not have the kind of expertise needed, FabLabs can show up as way to overcome the initial disadvantage regarding original players. Thus, the intensity of this force can be considered as low to medium.

As for the "Bargaining power of customers", information is what allows customers to negotiate better terms and conditions. If customers are aware of industry requirements and practices, they have more leverage to exert pressure on negotiations, as information can be seen as a source of power, making informed customers a threat for firms. As firms make available their products/services information mainly through websites, it allows to assert that customers can easily check that information online. For B2C models, customers will likely have no switching costs involved, which can influence brand loyalty. So, bargaining power of customers can be considered medium, varying from industry.

Regarding "Threat of substitutes", cheaper substitutes and alternatives from other sectors are a reality. Moreover, conventional processes seem to be more suitable to produce standard products. Taken this all together, the threat of substitutes can be considered at least medium.

When looking at "Bargaining power of suppliers", the suppliers' capacity for vertical integration, the existence of a small number of suppliers to respond to the sector needs, and the pressure that suppliers inflict on competition, puts this force intensity in medium. However, the ease in changing suppliers can balance the scale.

Lastly, for "Rivalry among existing competitors", AM technology is contributing to intensify competition, allowing rivalry to be seen as a new sector, where there exists a wide range of competitors using this technology and taking advantage of it to serve multiple markets. On the other hand, IPR, again portraited by the lack of regulatory system, show up as an opportunity for firms. Adding to what was described, the fact that technological advances are ensuring better access to AM technology knowledge, it can be said that rivalry among existing competitor is high.

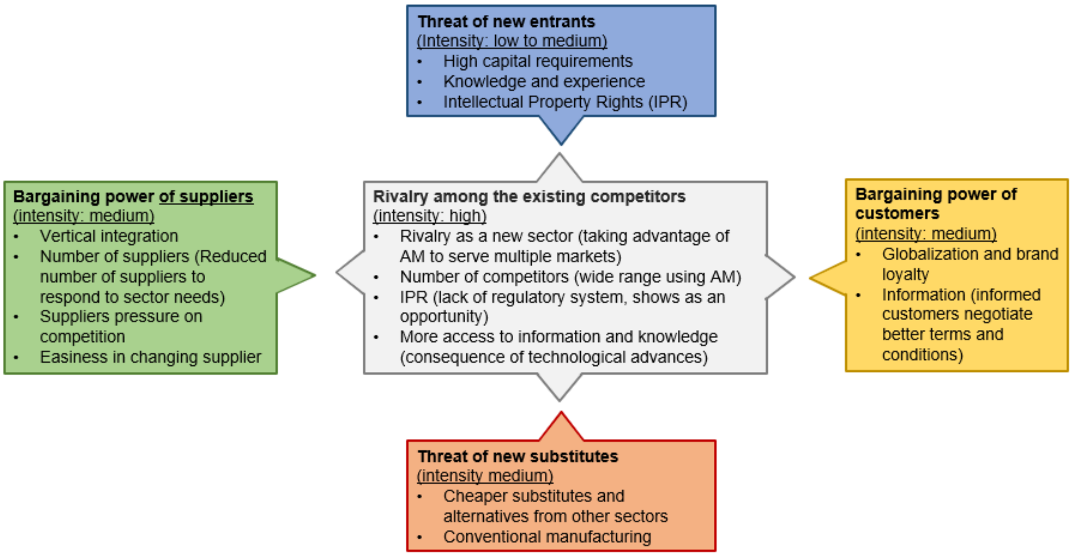

Figure 5.1- Porter's Five Forces model adapted to Portuguese AM industry

5.1 Contributions and Limitations

As this topic is an emerging area of research where tangible or case-based evidence are still scarce, knowledge and assessment models are crucial. Thus, the main impact that is expected with this work to the state of the art resides on the fact at the time of this study no other models illustrate Porter's Five Forces model (Porter, 1979) analysis for AM industry regarding firms' strategy area. Furthermore, to provide a model that can be adopted by researchers and stakeholders so that they can identify the factors that impact each actor of the sector, allowing them to shape their business strategy to the industry conditions. By making use of this type of analysis, researchers and stakeholders should be capable to determine which are the strengths and weaknesses of the industry in question which in turn allows them to know the market in detail. On the other hand, this model also contributes for the extension of the literature in the sense it gives a new perspective for conducting structural analysis, where Porter's Five Forces model considers knowledge economy.

Regarding the limitations of this study, although the implementation of knowledge management systems (KMS) may support firms with use of Industry 4.0 technologies, such as Additive Manufacturing, this dimension is not assessed by the case study meaning that the second research questions was not answered. This happens as no information regarding KM practices or how knowledge flows within the organization (how it is shared and managed) was gathered. The reason why KM is part of this work resides on the fact that, in the of case Additive Manufacturing, KM processes are even more important because firms act in disruptive and emerging industries whose business dynamics are not fully known. However, this is a limitation of the research instrument selected, as the questionnaire should not be very long and should capture the essential information for the study, which in this case are the influencing factors for conduct Porter's analysis.

On top of that, this study is based on a reduced sample, which can imply that the findings might be missing a step further than what was observed, meaning that in the narrowest sense that the conclusions only work for the firms in study. For generalization a larger scale study would be necessary. Nevertheless, the outcome of this study creates opportunities for further research on the topic of Additive Manufacturing business models.

5.2 Future Work

The author hopes that the research inspires additional study in this emerging field. As future work is suggested the study of the developed model in a corporate environment where the adoption of the Additive Manufacturing technology is at a more advanced level than the firms analyzed, e.g., that fully uses this technology to produce its products or services. Moreover, assess the implications for the industry under study and definition of an operational strategy for it.

Additionally, is crucial that forthcoming research reinforces the importance of knowledge management to streamline the use of new technologies, such as Additive Manufacturing, by studying KM practices and normative used by firms to assess the information regarding AM technologies.

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Annex

A.1 Questionnaire

Questionário sobre a utilização da tecnologia de Fabrico Aditivo em Portugal

A Unidade de Investigação e Desenvolvimento em Engenharia Mecânica e Industrial (UNIDEMI) em consórcio com o Centro de Estudos sobre a Mudança Socioeconómica e o Território (DINÂMIA'CET) e com o Instituto de Engenharia Mecânica (IDMEC), está a desenvolver um projeto de nome "Knowledge Management in Additive Manufacturing: Designing New Business Models (KM3D)", PTDC/EME-SIS/32232/2017, financiado pela Fundação para a Ciência e Tecnologia. Este projeto visa identificar e caracterizar os impactos da tecnologia de Fabrico Aditivo nos modelos de negócio, bem como estratégiasde gestão do conhecimento a adotar por forma a promover a competitividade e sustentabilidade do tecido industrial utilizador desta tecnologia em Portugal.

Com esta pesquisa pretendemos validar um modelo de análise estrutural da indústria no âmbito do Fabrico Aditivo.

A informação obtida através deste questionário constitui informação anónima de suportea este trabalho de investigação.

A sua colaboração é essencial, por isso agradecemos desde já a sua disponibilidade!

*Obrigatório

1. Concordo em prosseguir com este questionário e em participar nesta pesquisa? *

   Para prosseguir com este questionário, pedimos que assinale a sua concordância com esta pesquisa.

   Marcar tudo o que for aplicável.

   - [ ] Sim

2. A sua Empresa utiliza a tecnologia de Fabrico Aditivo em alguma área do seu processo produtivo? *

Marcar apenas uma oval.

- ( ) Sim *Avançar para a pergunta 3*
- ( ) Não *Avançar para a secção 3 ()*

Agradecemos a sua disponibilidade!

Informação sobre o Inquirido

3. Indique a sua função na Empresa:

Marcar apenas uma oval.

- ( ) Diretor de Engenharia e Inovação
- ( ) Diretor Geral
- ( ) Diretor de Investigação e Desenvolvimento
- ( ) Diretor de Qualidade
- ( ) Diretor Técnico
- ( ) Gestor de Manutenção
- ( ) Gestor de Operações
- ( ) Gestor de Produção
- ( ) Gestor de Projeto
- ( ) Outra: ____________________

4. Quais as suas habilitações? *

Marcar apenas uma oval.

- ( ) Formação/Aprendizagem autónoma
- ( ) Pós-graduação
- ( ) Formação profissional
- ( ) Bacharelato
- ( ) Licenciatura
- ( ) Mestrado
- ( ) Doutoramento

5. Indique o número de anos de experiência profissional nesta Empresa: *

Marcar apenas uma oval.

- ◯ Menos de 1 ano
- ◯ Entre 1 e 3 anos
- ◯ Entre 3 e 5 anos
- ◯ Entre 5 e 10 anos
- ◯ Mais de 10 anos

6. Na sua função atual tem algum contacto com a tecnologia de Fabrico Aditivo? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não

Caracterização da Empresa

7. Nome da Empresa: *

____

8. Selecione o(s) distrito(s) onde está localizada a Empresa em Portugal: *

Marcar tudo o que for aplicável.

- ☐ Viana do Castelo
- ☐ Braga
- ☐ Vila Real
- ☐ Bragança
- ☐ Porto
- ☐ Aveiro
- ☐ Guarda
- ☐ Castelo Branco
- ☐ Leiria
- ☐ Santarém
- ☐ Portalegre
- ☐ Lisboa

- [ ] Setúbal
- [ ] Beja
- [ ] Faro

9. Indique o setor principal de atividade económica (CAE):

____

10. Indique o número de trabalhadores da sua Empresa: *

Marcar apenas uma oval.

- ( ) Menos de 10
- ( ) Mais de 10 e menos de 50
- ( ) Mais de 50 e menos de 250
- ( ) Mais de 250

11. Indique qual o volume de negócios anual (médio) da sua Empresa:

Marcar apenas uma oval.

- ( ) Menos de 2 000 000€
- ( ) Mais de 2 000 000€ e menos de 10 000 000€
- ( ) Mais de 10 000 000€ e menos de 50 000 000€
- ( ) Mais de 50 000 000€

12. Indique qual/quais as principais áreas de negócio. *

____

13. Na sua área de produção qual é a quota de mercado da Empresa face aos seus principais concorrentes? *

Marcar apenas uma oval.

- ( ) Tem menos de 5 % da quota de mercado
- ( ) Tem de 5 a 10 % da quota de mercado
- ( ) Tem a 10 a 20 % da quota de mercado
- ( ) Tem de 20 a 40% da quota de mercado
- ( ) Tem de 40 a 50 % da quota de mercado
- ( ) Tem mais de 50 % da quota de mercado

Caracterização da utilização da tecnologia de Fabrico Aditivo na Empresa

14. Qual o tipo de Tecnologia Aditiva empregue? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- [ ] Fused Deposition Modeling (FDM)
- [ ] Inkjet Printing (IJP)
- [ ] Laser Powder Bed Fusion (LPBF)
- [ ] Laser Engineered Net Shaping (LENS)
- [ ] Stereolithography (SLA)
- [ ] Selective Laser Sintering (SLS)
- [ ] Digital Light Processing (DLP)
- [ ] Three-dimensional Printing (3DP)
- [ ] Outra tecnologia

15. Se na pergunta anterior selecionou 'Outra tecnologia' indique a Tecnologia Aditiva a que se refere.

____

16. Indique há quanto tempo a Empresa utiliza a tecnologia de Fabrico Aditivo. *

Marcar apenas uma oval.

- ( ) Menos de 1 ano
- ( ) Entre 1 e 3 anos
- ( ) Entre 3 e 5 anos
- ( ) Entre 5 e 10 anos
- ( ) Mais de 10 anos

17. Para que fim é utilizada a tecnologia de Fabrico Aditivo nos processos da Empresa? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- [ ] Produção de protótipos para uso interno
- [ ] Produção de protótipos para venda ao cliente
- [ ] Produção de componentes para uso interno
- [ ] Produção de componentes para incorporação no produto final
- [ ] Produção do produto final
- [ ] Produção de ferramentas

- ☐ Produção de moldes para fundição de metal
- ☐ Produção de moldes para ferramentas de
- ☐ prototipagemModelos de apresentação
- ☐ Investigação
- ☐ Outra:

18. Indique outros métodos de produção que são utilizados em simultâneo com a tecnologia de Fabrico Aditivo. Pode selecionar mais que uma opção, se aplicável. *

    Marcar tudo o que for aplicável.

    - ☐ Corte por laser
    - ☐ Corte por jato de água
    - ☐ Eletroerosão
    - ☐ Máquinas CNC
    - ☐ Moldagem por injeção
    - ☐ Maquinagem
    - ☐ Outra:

19. Qual o peso da produção com recurso à tecnologia de Fabrico Aditivo no negócio da sua Empresa? *

    Marcar apenas uma oval.

    - ◯ 0%
    - ◯ Mais de 1% e menos de 5%
    - ◯ Mais de 5 % e menos de 10%
    - ◯ Mais de 10% e menos de 20%
    - ◯ Mais de 20% e menos de 40 %
    - ◯ Mais de 40 % e menos de 50%
    - ◯ Mais de 50%

20. Na sua opinião quais as áreas do processo produtivo que beneficiaram mais pelo uso da tecnologia de Fabrico Aditivo? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- [ ] Design
- [ ] Velocidade de produção
- [ ] Customização da produção
- [ ] Flexibilidade da produção
- [ ] Dimensão dos lotes
- [ ] Adaptabilidade
- [ ] Simplificação da cadeia de abastecimento
- [ ] Diminuição do desperdício
- [ ] Outra:

21. Qual o número de colaboradores com conhecimento na área da produção aditiva? *

Marcar apenas uma oval.

- 1-3
- 3-5
- 5-7
- 7-10
- Mais de 10

22. Qual o nível de escolaridade mais avançado desses colaboradores? *

Marcar apenas uma oval.

- Curso profissional
- Bacharelato
- Licenciatura
- Mestrado
- Doutoramento

23. Existe dificuldade em recrutar colaboradores qualificados em Fabrico Aditivo nesta área? *

Marcar apenas uma oval.

- Sim
- Não

24. De que forma a sua Empresa adquire conhecimento sobre a tecnologia de Fabrico Aditivo? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- ☐ Colaboração com o meio académico
- ☐ Formação por terceiros
- ☐ Aprendizagem autónoma
- ☐ Outra:

25. De que forma a sua Empresa protege o conhecimento detido relativo à tecnologia de Fabrico Aditivo? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- ☐ Não existe
- ☐ Patentes
- ☐ Modelos de utilidade
- ☐ Segredo industrial em conjunto com acordos de confidencialidade
- ☐ Direitos de cópia
- ☐ Outra:

26. Quanto investiu a sua Empresa na tecnologia de Fabrico Aditivo, no último ano? Tenha em mente custos com software, equipamento e mão de obra (contratação e/ou formação).

Marcar apenas uma oval.

- ◯ Menos de 1000€
- ◯ Mais de 1000€ e menos de 10 000€
- ◯ Mais de 10 000€ e menos de 50 000€
- ◯ Mais de 50 000 e menos de 100 000€
- ◯ Mais de 100 000€

27. Indique qual a sua perceção relativamente às seguintes afirmações tendo em conta o contexto da tecnologia de Fabrico Aditivo bem como as alterações que esta trouxe à realidade da sua Empresa e do setor. *

Marcar apenas uma oval por linha.

	Discordo totalmente	Discordo	Concordo	Concordo completamente	Não sei
Empresas já estabelecidas possuem recursos parra combater a entrada de novos concorrentes.	⬭	⬭	⬭	⬭	⬭
A entrada de novos concorrentes requer grandes investimentos em equipamento, mão--de-obra e/ou Pesquisa e Desenvolvimento.	⬭	⬭	⬭	⬭	⬭
A falta de um sistema de regulamentação torna mais fácil o sucesso de uma nova empresa. (Por exemplo, problemas relativos a direitos de propriedade intelectual).	⬭	⬭	⬭	⬭	⬭

28. Os vossos clientes podem aceder a informações sobre os produtos/serviços através de: Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- ☐ Atividade comercial
- ☐ Site
- ☐ Revista
- ☐ Atividade comercial

- [ ] Loja
- [ ] Marketplace
- [ ] Não aplicável
- [ ] Outra:

29. Os vossos clientes participam no processo de desenvolvimento do produto/serviço? Se sim, selecione abaixo as opções que mais se adequam. *

Marcar tudo o que for aplicável.

- [ ] O cliente não participa
- [ ] Geração de ideias
- [ ] Design
- [ ] Testagem, i.e., contribui na testagem e deteção de falhas do produto
- [ ] Suporte, i.e., contribui na resolução de problemas
- [ ] Marketing

30. Que atividades compreendem o vosso serviço de pós-venda? Pode selecionar mais que uma opção, se aplicável. *

Marcar tudo o que for aplicável.

- [ ] Atendimento ao cliente
- [ ] Comunicação de serviços
- [ ] Oferta de serviços complementares
- [ ] Suporte/Assistência
- [ ] Reparações
- [ ] Garantias
- [ ] Trocas e devoluções
- [ ] Outra:

31. Os produtos/serviços comercializados pela sua Empresa são rastreáveis durante o seu ciclo de vida? *

Marcar apenas uma oval.

- ( ) Não é possível
- ( ) Os produtos podem ser rastreados à medida que se movem entre os locais defa-bricação e de distribuição interna
- ( ) Os produtos podem ser rastreados durante a fabricação e distribuição até chegarem ao cliente
- ( ) Os produtos podem ser rastreados durante todo o ciclo de vida completo

32. Previsão de crescimento do mercado para os vossos produtos/serviços em relação ao total atual de vendas. *

Marcar apenas uma oval.

- 0%
- 1%-5%
- 5%-10%
- 10%-20%
- Mais de 20%

33. Indique qual a sua perceção relativamente às seguintes afirmações tendo em conta o contexto da tecnologia de Fabrico Aditivo bem como as alterações que esta trouxe à realidade da sua Empresa e do setor. *

Marcar apenas uma oval por linha.

	Discordo totalmente	Discordo	Concordo	Concordo completamente	Não sei
A introdução da tecnologia de Fabrico Aditivo permitiu que os nossos clientes tenham elevado poder de negociação nas transações realizadas.					
O fácil acesso à produção com a tecnologia de Fabrico Aditivo permitiu que os nossos clientes entrem como concorrentes no setor.					
Os nossos clientes possuem conhecimento/informação suficiente sobre o setor para avaliar a qualidade e valor dos produtos.					
Os nossos clientes são principalmente grossistas e retalhistas com poder parra influenciar a compra dos consumidores finais.					
As necessidades a que os nossos produtos dão resposta podem ser satisfeitas por produtos de outros setores.					

Existe uma pressão considerável de produtos substitutos mais baratos.	⬭	⬭	⬭	⬭	⬭
Existem produtos substitutos com melhor relação preço-desempenho.	⬭	⬭	⬭	⬭	⬭
A utilização da tecnologia de Fabrico Aditivo para a produção de produtos standard não representa uma mais-valia parra a Empresa.	⬭	⬭	⬭	⬭	⬭
Os clientes têm facilidade em recorrer a outras Empresas em vez do nosso serviço pós-venda.	⬭	⬭	⬭	⬭	⬭

34. A maioria dos fornecedores da sua Empresa tem localização geográfica: *

Marcar apenas uma oval.

- Nacional
- Internacional

35. Em que medida os vossos fornecedores estão integrados nos processos da organização? *

Marcar apenas uma oval.

- Comunicação reativa com os fornecedores
- Comunicação básica e partilha de dados quando necessário com os fornecedores
- Partilha de repositórios de dados ou base de dados
- Sistemas totalmente integrados com fornecedores para apoio ao processo (por exemplo, planeamento integrado em tempo real)
- Não aplicável

36. Indique qual a sua perceção relativamente às seguintes afirmações tendo em conta o contexto da tecnologia de Fabrico Aditivo bem como as alterações que esta trouxe à realidade da sua Empresa e do setor. *

Marcar apenas uma oval por linha.

	Discordo totalmente	Discordo	Concordo	Concordo completamente	Não sei
Os fornecedores têm facilidade em se alinhar com o nosso processo de produção.	⬭	⬭	⬭	⬭	⬭
Os fornecedores têm facilidade em aumentar os preços ou reduzir a qualidade dos produtos.	⬭	⬭	⬭	⬭	⬭
Existe um pequeno número de fornecedores que dá resposta a uma grande proporção das matérias-primas do setor.	⬭	⬭	⬭	⬭	⬭
A concorrência é fortemente influenciada pelo poder de negociação dos fornecedores.	⬭	⬭	⬭	⬭	⬭
As Empresas que atuam neste setor conseguem facilmente mudar de fornecedores.	⬭	⬭	⬭	⬭	⬭
A competitividade das Empresas que utilizam o Fabrico Aditivo é intensa.	⬭	⬭	⬭	⬭	⬭
Existe uma grande diversidade de concorrentes que	⬭	⬭	⬭	⬭	⬭

utilizam a tecnologia de Fabrico Aditivo.					
O uso da tecnologia de Fabrico Aditivo permite que as Empresas deste setor sirvam diferentes mercados.					
Alterações na nossa estratégia tem efeitos percetíveis nas Empresas concorrentes.					
A falta de um sistema de regulamentação para direitos autorais apresenta-se como uma oportunidade parra as Empresas.					
Os avanços tecnológicos permitem um melhor acesso ao conhecimento de tecnologias de Fabrico Aditivo					

37. Estaria disponível para uma possível entrevista no âmbito do projeto? *

Marcar apenas uma oval.

Sim *Avançar para a pergunta 38*

Não *Avançar para a secção 7 ()*

Agradecemos a sua disponibilidade!

Agradecemos a sua disponibilidade!
Caso pretenda receber mais informação sobre esta pesquisa por favor deixe-nos os seus dados para contacto.

38. Nome *

39. Email *

A.2 Statements regarding Porter's Five Forces Model Proposal

Affirmation	Description
1	Established firms have the resources to fight the entry of new competitors.
2	The entry of new competitors requires large investments in equipment, hand- labor and/or R&D.
3	The lack of a regulatory system makes it easier for a new firm to succeed. (For example, issues relating to intellectual property rights).
4	The introduction of Additive Manufacturing technology allowed our customers to have high bargaining power in the transactions carried out.
5	Easy access to production with Additive Manufacturing technology has allowed our customers to enter as competitors in the sector.
6	Our customers have enough knowledge/information about the industry to assess the quality and value of products.
7	Our customers are mainly wholesalers and retailers with the power to influence the purchase of final consumers.
8	The needs that our products meet can be met by products from other sectors.
9	There is considerable pressure for cheaper substitute products.
10	There are substitute products with a better price- performance.
11	The use of Additive Manufacturing technology to produce standard products does not represent added value for the firm.
12	Customers find it easy to use other firms instead of our after-sales service.
13	Suppliers find it easy to align themselves with our production process.
14	Suppliers find it easy to raise prices or reduce product quality.
15	There are a small number of suppliers that respond to a large proportion of the sector's raw materials.
16	Competition is strongly influenced by the bargaining power of suppliers.
17	Firms operating in this sector can easily change their supplier.
18	The competitiveness between firms that use Additive Manufacturing is intense.
19	There is a wide variety of competitors that use the Additive Manufacturing technology.
20	The use of Additive Manufacturing technology allows firms in this sector to serve different markets.
21	Changes in our strategy have noticeable effects on competing firms.
22	The lack of a regulatory system for copyright presents an opportunity for firms.
23	Technological advances allow better access to knowledge of Additive Manufacturing technologies.

A.3 Grey Relational Analysis Sector C: Manufacturing Industries

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
B	1	4	4			3	3	3	2	3		3	3	2	2	2	3	3	3
C	3	3	2	3	2	2	4	2	3	3	2	3	3	3	2	3	3	3	3
E	2	4	3	2	1	3	2	4		3	2	3	3	4	3	3	3	1	3
F	2	3	2																
G	2	3	3			4	2	2	2	2	3	3	2	3				3	3
I	2	4	3	3	3	4	4	2	3	3	2	4	4	3	2	2	4	4	
J	2	2	2	2	3	3	1	3	2	2	3	3	4	3	3	3	2	3	3
L	2	3	3			3	1	3	2	3	3	3	3	3	3	3	3		
M	2	4	2	2	1	3	2	2	2	3	2	2	3	3	3	2	4	3	3

Annex A.3.1- Comparing data series generation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
Reference data series	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**4**	**4**	**4**	**4**	**4**
B	3	0	0			1	1	1	2	1		1	1	1	2	2	1	1	1
C	1	1	2	1	2	2	0	2	1	1	2	1	1	2	2	1	1	1	1
E	2	0	1	2	3	1	2	0		1	2	1	1	3	1	1	1	3	1
F	2	1	2																
G	2	1	1			0	2	2	2	2	1	1	2	2				1	1
I	2	0	1	1	1	0	0	2	1	1	2	0	0	2	2	2	0	0	
J	2	2	2	2	1	1	3	1	2	2	1	1	0	2	1	1	2	1	1
L	2	1	1			1	3	1	2	1	1	1	1	2	1	1	1		
M	2	0	2	2	3	1	2	2	2	1	2	2	1	2	1	2	0	1	1

Annex A.3.2- Data series difference calculation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22	**General concordance**
B	0,333	1,000	1,000			0,600	0,600	0,600	0,429	0,600		0,600	0,600	0,600	0,429	0,429	0,600	0,600	0,600	0,601
C	0,600	0,600	0,429	0,600	0,429	0,429	1,000	0,429	0,600	0,600	0,429	0,600	0,600	0,429	0,429	0,600	0,600	0,600	0,600	0,558
E	0,429	1,000	0,600	0,429	0,333	0,600	0,429	1,000		0,600	0,429	0,600	0,600	0,333	0,600	0,600	0,600	0,333	0,600	0,562
F	0,429	0,600	0,429																	0,486
G	0,429	0,600	0,600			1,000	0,429	0,429	0,429	0,429	0,600	0,600	0,429	0,429				0,600	0,600	0,543
I	0,429	1,000	0,600	0,600	0,600	1,000	1,000	0,429	0,600	0,600	0,429	1,000	1,000	0,429	0,429	0,429	1,000	1,000	1,000	0,714
J	0,429	0,429	0,429	0,429	0,600	0,600	0,333	0,600	0,429	0,429	0,600	0,600	1,000	0,429	0,600	0,600	0,429	0,600	0,600	0,535
L	0,429	0,600	0,600			0,600	0,333	0,600	0,429	0,600	0,600	0,600	0,600	0,429	0,600	0,600	0,600			0,548
M	0,429	1,000	0,429	0,429	0,333	0,600	0,429	0,429	0,429	0,600	0,429	0,429	0,600	0,429	0,600	0,429	1,000	0,600	0,600	0,538
Sector's average concordance	0,437	0,759	0,568	0,497	0,459	0,679	0,569	0,564	0,478	0,557	0,502	0,629	0,679	0,438	0,527	0,527	0,690	0,619	0,657	

Annex A.3.3- Grey relation coefficient and grey relational grade calculation

A.4 Grey Relational Analysis Sector G: Wholesale and Retail Trade; Cars and Motorcycles Vehicle Repair

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
A	2	2	4		1	3	1	4	3	1	1	2	3	2	3	3	3	2	4
D	3	3	2	2	3	2	3	3	3	2	2	3	3	3	3	3	3	2	2
K	2	3	3	3	2	2	2	3	2	3	2	3	4	2	2	2	4	4	4

Annex A.4.1- Comparison data series generation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
Reference data series	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**4**	**4**	**4**	**4**	**4**
A	2	2	0		3	1	3	0	1	3	3	2	1	1	1	1	1	2	0
D	1	1	2	2	1	2	1	1	1	2	2	1	1	2	1	1	1	2	2
K	2	1	1	1	2	2	2	1	2	1	2	1	0	1	2	2	0	0	0

Annex A.4.2-Data series difference calculation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22	**General concordance**
A	0,429	0,429	1,000		0,333	0,600	0,333	1,000	0,600	0,333	0,333	0,429	0,600	0,600	0,600	0,600	0,600	0,429	1,000	0,569
D	0,600	0,600	0,429	0,429	0,600	0,429	0,600	0,600	0,600	0,429	0,429	0,600	0,600	0,429	0,600	0,600	0,600	0,429	0,429	0,528
K	0,429	0,600	0,600	0,600	0,429	0,429	0,429	0,600	0,429	0,600	0,429	0,600	1,000	0,600	0,429	0,429	1,000	1,000	1,000	0,612
Sector's average concordance	0,486	0,543	0,676	0,514	0,454	0,486	0,454	0,733	0,543	0,454	0,397	0,543	0,733	0,543	0,543	0,543	0,733	0,619	0,810	

Annex A.4.3- Grey relation coefficient and grey relational grade calculation

A.5 Grey Relational Analysis Sector M: Consulting, Scientific, Technical and Similar Activities

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
H		3	3		3	3	3	3	2	3	2	4	4	4	3	3	3	3	3

Annex A.5.2- Comparison data series generation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22
Reference data series	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**4**	**4**	**4**	**4**	**4**
H		1	1		1	1	1	1	2	1	2	0	0	3	1	1	1	1	1

Annex A.5.1- Data series difference calculation

Firm ID	Affirm.1	Affirm.2	Affirm.3	Affirm.4	Affirm.5	Affirm.6	Affirm.8	Affirm.11	Affirm.12	Affirm.13	Affirm.14	Affirm.15	Affirm.16	Affirm.17	Affirm.18	Affirm.19	Affirm.20	Affirm.21	Affirm.22	**General concordance**
H		0,600	0,600		0,600	0,600	0,600	0,600	0,429	0,6	0,429	1	1	0,333	0,600	0,600	0,600	0,600	0,600	0,611

Annex A.5.3- Grey relation coefficient and grey relational grade calculation

2022

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