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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, in the past few decades AM has been gaining visibility due to technological evolution and due to the need to increase differentiating factors to overtake competitors. Coupled with this, phenomenon such as increased firms' competitivity and rivalry, increased customer demand and diversity and the shift from an industrial economy to a knowledge-based economy are leading to the emergence of new business models. However, despite of AM's business possibilities, in literature it is missing a model to analyse the impact of AM in business strategy. Accordingly, the present research focuses on understanding how AM impacts firms' business strategy. To achieve that objective, is proposed an adaptation of Porter's Five Forces Model to aid in positioning firms' strategy when using AM. The model was applied to 13 organisations operating with AM in Portugal. It was possible to conclude that all the participating firms, except one, fit in the incremental stream of development as regards to AM technology, where AM technologies appear as a complementing technology. Also, 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.

Keywords: Additive Manufacturing; Porter's Five Forces model; Case study research.

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1. Introduction

Global markets have had to increase their pace to keep up with the constant technological evolution [1]. New disruptive technologies are creating space for the emergence of new types of business and production models that arise in response to digital transformation, requiring high levels of efficiency and flexibility [2]. As a consequence, organizations have to be diligent and look for ways to strengthen their market position and gain competitive advantage [3]. Additive Manufacturing (AM) stands out as an emerging technology with the potential to disrupt classical business models. Being a disruptive technology with innovative and complex products, the implementation of AM requires good process management as the dynamics of new business models are not yet known [1]. As a result, companies are facing several challenges as the traditional ways of doing business are being changed. Thus, organizations are being forced to rethink their business models (BMs) [4].

The importance of developing and employing an appropriate business model that is aligned with the companies' value proposition stems from the fact that simply using good technology is not enough [5]. R. Godina et al. (2020) [6] argues that since this topic is an emerging research area, tangible or case-based evidence is still scarce and knowledge and evaluation models are crucial. In this sense, the present research intends to fill this gap by aiming to investigate the impact of AM on business strategy. In previous research, a model based on Porter's Five Forces [7] adapted to MA was developed. In a first phase, the development of the model consisted in identifying constructs that fit the perspectives of MA in Porter's forces. The present article reports on the second phase of the research, where the results of the application of the model developed in 13 Portuguese companies using AM are presented.

The article is structured as follows: in section 2, is presented the state-of-the-art in AM business models and strategy; in section 3, is presented the proposed the adapted Porter's Five Forces Model and the survey method; in section 4 are presented the results of the survey; section 5 provides the discussion on the results; last, in section 6, are presented the main conclusions for this research.

2. Literature review

2.1. Industry 4.0 as propulsor of Additive Manufacturing

Industry 4.0, also known as the Fourth Industrial Revolution, has been a turning point for a new era in manufacturing, leading to the digitization of business models, environment, production systems and machines, among others [8]. Artificial Intelligence (AI), Internet of Things (IoT), Big Data, Cloud Computing, Additive Manufacturing (AM), Augmented Reality (AR) and Machine Learning are technologies that form the basis of Industry 4.0 that have revolutionized manufacturing systems and everyday life [9].

Additive Manufacturing (AM) stands out as a technology that mimics biological processes by additively building parts in layers. In the context of Industry 4.0, AM emerges as a key technology for this digitized and smart era, enabling rapid product development through an additive process rather than the usual subtractive or molding forms of traditional manufacturing [6]. In general, the current stages of AM implementation in the production process can be summarized into three main parts [10]: model creation/reverse engineering; printing; and finishing process.

The relevance of AM lies in the fact that the manufacturing paradigm is likely to shift from mass production to mass customization as a consequence of consumers taking a more active voice in the production process, either as agents of co-innovation or of choosing predetermined options to compose the final product as best satisfies them [11]. Another phenomenon in focus is the emergence of smart factories. Due to their modular nature, these types of factories have the ability to change and reconfigure flexibly in order to respond quickly to customer needs and, consequently, product changes [12].

2.2. Factors affecting firms' strategy

The advances in AM lead to the emergence of new business models [4], and, as consequence, companies are force to rethink their positioning. To address the strategic impact of AM, in prior research (see [13]) was suggested to track the influence of AM in firms' strategy using the Porter's Five Forces Model [7]. Hence, we address literature findings on the perspective of each force.

Threat of new entrants

Extended Producer Responsibility, introduced by [14], has made it mandatory for producers to accept returned products and waste that remains after those products have been used. This implies that producers need to have resources to deal with the product at the end of the life cycle, either as labor capacity, space and/or financial funds [15]. This can appear as a barrier to small producers who may want to enter but do not already have the infrastructure to do so.

From a knowledge perspective, early adopters of AM gain an advantage over later adopters. In addition to this fact, attracting skilled labor is vital [16], [17].

Intellectual Property Rights (IPR) will also play an important role when it comes to the threat of new entry. The lack of IPR protection or the expiration of patents could give an advantage to other organizations or consumers who take advantage of this unregulated knowledge [18]. The dichotomy around IPR is that, depending on the perspective, it can be an opportunity or a challenge for new entrants [17].

Bargaining power of customers

In this strength is the introduction of Extended Consumer Liability legislation, Democratization of manufacturing, Globalization and information sharing. The introduction of Extended User Responsibility has given consumers the right to repair their own products, something that may be enhanced by "prosumerism" [24]. The latter has been made possible because AM is increasingly accessible to the consumer - democratization of manufacturing.

In addition, the growth of information technology also allows the consumer to have access to more information and to shop online, not only locally but also globally [3].

Threat of substitutes

There are two main threats of substitutes using AM technology. On the one hand, the modularity facet of this type of product empowers the emergence of "swap 'n' go" suppliers. A swap 'n' go vendor is a qualified manufacturer that is certified to make updates or repairs to the product design, allowing individuals to not throw away or replace their products [15]. On the other hand, AM cannot compete entirely with conventional manufacturing in the field of mass production, for example, standard products that pose a high threat depending on the industry in which the organization operates [19].

Bargaining power of suppliers

One of the most popular consequences of AM, is the decentralization of supply chains, and consequently its shortening. AM is digitizing supply chains (SCs) both by empowering the shift from physical to digital inventory since [20], [21]. The decentralization of SCs is threating suppliers' power as "glocalization" is placing manufacture closer to the final customer.

Also, as "Bargaining power of suppliers" is the flip side of "bargaining power of customers", the democratization of manufacturing will also affect this force. Thus, "prosumers" will similarly to other suppliers on industry constitute a threat [20]. Nevertheless, AM turns feasible the adoption of vertical integration by suppliers which allows them to take advantage of both decentralized nature of new SCs and resources already detained [22].

Rivalry among the existing competitors

Bearing in mind that MA is an expanding technology that is more flexible than traditional methods, it becomes possible that each company can serve different markets simultaneously, with rivalry emerging as a new sector [20].

The environmental awareness of various players, as well as emerging environmental regulations, has tended to increase the demand for value-added products with long life cycles [15]. This phenomenon may press this strength due to the phenomenon of globalization, as organizations compete globally.

It should also be noted that the progress made in IT and the emergence of disruptive technologies are giving organizations more access to information and knowledge, which allows them to be more competitive [23].

Finally, the increasing availability of 3D printing services will potentially empower prosumers with equipment, knowledge, and information (e.g., through FabLabs) that enables them to produce their own products. Along with this comes the issue regarding IPR, as there is no regulatory system to control [17].

3. Proposed method

To study the impact that AM has in firms' business strategy, this research proposes an adaptation of Porter's Five Forces Model. Prior research consisted in developing a conceptual model that systematizes the AM influence in strategy according to the Porter's five forces (see Figure 1). Details on the model development and theoretical validation can be consulted in [13]. For each force in the model were identified the main AM drivers that enable or constrain firms' strategical positioning.

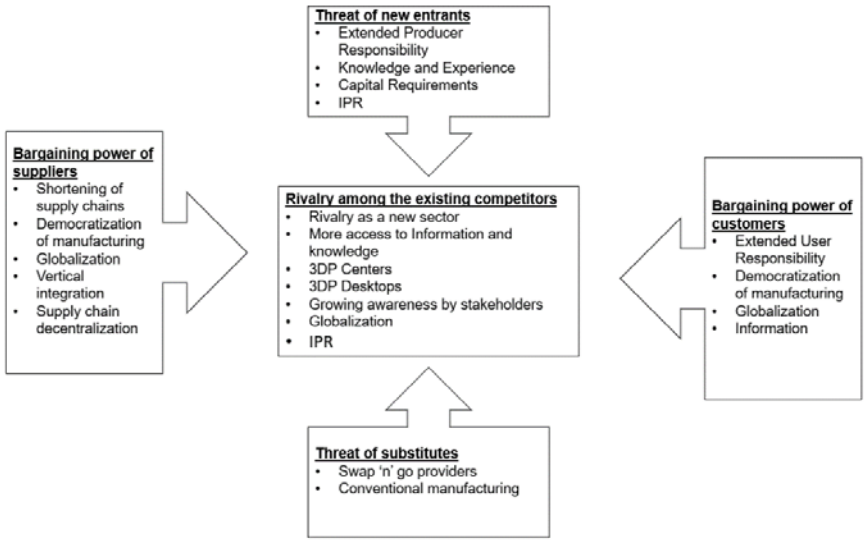

Figure 1. Porter's five forces model applied to Additive Manufacturing [13].

This article focuses on the application of the proposed model in industry. 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.

Case study research is the methodology chosen to conduct this study. As this research intent 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 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 [24, p. 1] 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 phenomenon, but it also provides a methodical way to look at events, collecting data, analyzing evidence and report the results [25]. 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 [26].

The questionnaire is the research instrument chosen to respond to the three latter points of Porter's guidelines. 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 any time and any-where) [27]. The

questionnaire consists of a questionnaire addressing the key AM constructs associated with each force as represented in Figure 1 and explained in section 2.2.

The questionnaire was developed in a web platform and disseminated by email, where a brief description of the research held was given as well as the URL link to access to it. Later, answers were cross-checked with the inquired firms by online meetings.

4. Results

4.1. Sample characterization

The firms were selected to participate in the study based on their usage of AM on the firm's productive process. The universe of respondents is composed by thirteen firms operating in Portugal. The method adopted to select the elements of the sample was expert sampling which is a non-probabilistic procedure [28]. The respondents from the firms occupy positions at top/mid-level management. 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.

Regarding experience within the firm, most of the respondents have worked there for at least three years. As most of them have contact with AM technology, plus their experience and role within the firm, this sample seems to gather the characteristics needed for this study.

4.2. Threat of new entrants

In table 1 are presented the results regarding Threat of New Entrants force.

Table 1. Questionnaire results regarding "Threat of new entrants" force

Key Factor	Factor	Results
Extended Producer Responsibility (EPR)	Product traceability	23% firms track entire product life cycle
		31% do not track the product at all
Knowledge and Experience	Nr. of employees in AM	84% have 3 employees or less working in AM
		The maximum of employees is 10
	Education	69% Bachelors
		31% MSc
	Difficulty to recruit AM talent	77% find difficult to recruit AM workers
	Sources of knowledge	47% autonomous learning
		32% third party learning
		31% collaboration with academia
Capital Requirements	Investment in AM	31% firms invest less than € 1,000
		31% invest between € 1,000 and € 10,000
		15% invest between € 10,000 and € 50,000
		15% invest more than € 50,000
		8% did not respond
Intellectual Property Rights (IPR)	Knowledge protection	77% of firms don't protect IPR
		23% use utility models, confidentiality agreements and patents

Regarding EPR, the objective is to test the feasibility and time required to introduce EPR. For that the participating firms were asked about the level of traceability of their products/services. 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 automotive are already prepared to implement the EPR law since it is already possible to know the origin of the products through the serial numbers on it. Figure 2 shows the existing possibilities for tracking and frequency of each.

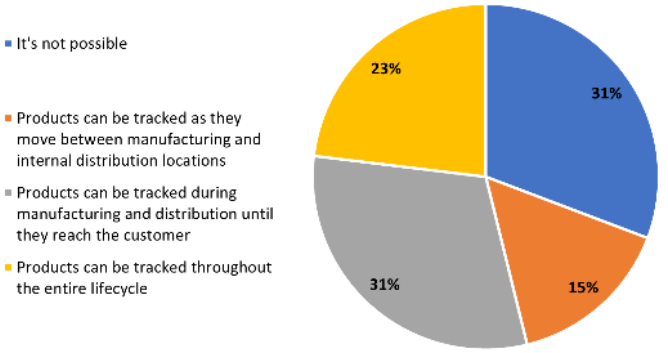

Figure 2. Product/service traceability.

Concerning Knowledge and Experience, the focus is to identify how many employees work with AM technologies, their education, whether there is difficulty in recruiting qualified personnel to work with AM technologies and how firms acquire knowledge about those technologies. 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 AM to support rather than to produce. For these same workers, the most advanced level of education is, in general, bachelor's degree (69%). 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.

About whether there is difficulty in recruiting qualified personnel to operate with AM technologies, most of the firms (77%) agree that it is difficult. 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.

As regard to capital requirements firms were asked about investments made on AM 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.

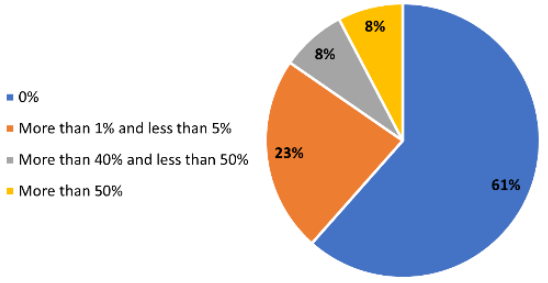

Figure 3. Weight of production using AM on the business.

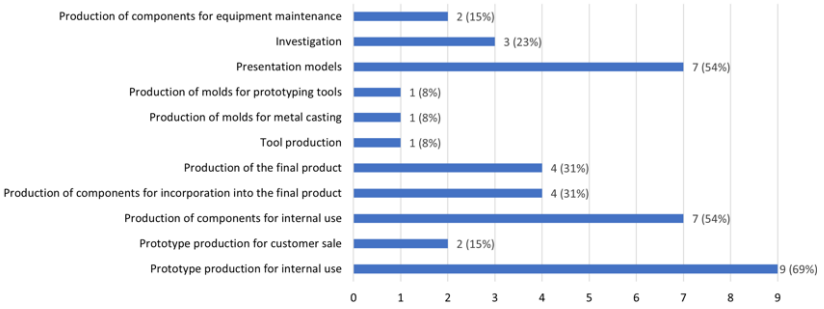

Figure 4. AM usage purpose.

Most of the firms (62%) spent less than 10 000€ in the last year, which is in line with the weight of production using AM on the business and the purposes of use showed in Figure 3 and 4. 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 AM technologies the most, namely fused deposition modelling, selective laser sintering or stereolitography, 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.

Lastly regarding the Intellectual Property Rights, firms were asked about how they protect the knowledge held concerning AM technology. As should be expected, most of the firms (77%) do not use any method available to protect the knowledge regarding AM 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.

4.3. Bargaining power of customers

Results regarding the Bargaining power of customers are presented in table 2.

Table 2. Questionnaire results regarding "Bargaining power of customers" force

Key Factor	Factor	Results
Extended User Responsibility (EUR)	After-sales services offered	54% offer support
		46% have customer service
		38% repair customer products
Democratization of Manufacturing	Consumers' participation in manufacturing process	69% participate in product design
		46% participate in ideas generation
		38% contributes to testing and detecting product failures
	Prosumerism – Consumers as producers (new competitors)	38% disagree or totally disagree
		31% agree
		31% no opinion
Globalization and Information	Product information dissemination	77% have a product website
		62% provide product information through business activities

Regarding EUR the objective is to understand the feasibility regarding the introduction of the EUR 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.

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 de-liver 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 with-out 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.

As for the democratization of manufacturing the intent 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. The top 3 areas where most of the firms confirm customers' contribution are design (69%), ideas generation (46%) and product testing (38%). 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". 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.

Lastly concerning globalization and information, these two factors are analyzed together because the availability of information through non-face-to-face ways allows customers to buy globally. 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%).

4.4. Threat of new substitutes

Results regarding the Threat of Substitutes are presented in table 3.

Table 3. Questionnaire results regarding "Threat of new substitutes" force

Key Factor	Results
General Aspects	54% disagree that their products are easily replaced by substitutes from other sectors
	85% feel the pressure for cheaper substitutes
	77% don't believe that AM substitutes have better price/performance
Swap 'n' go Providers	54% don't feel threatened by other firms' after-sales services
Conventional Manufacturing	62% don't believe AM is a good method to produce standard products

To understand how these factors influence this force, firms were asked to give their opinion about some statements. The statements given explored topics such as substitute products, after-sales services, and conventional manufacturing vs additive manufacturing. From the information depicted in Table 2 is possible to conclude that 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.

As for pressure of cheap substitutes, most of the participating firms show unanimity in their opinion. Still, most of the firms disagree that exist substitute products with better price-performance. Regarding after-sales services most of the participating firms disagree that customers find it easier to resort to other firms for repairs or upgrades instead of theirs.

Concerning AM technology as a direct way of manufacturing, most of the firms (62%) agree that AM does not add value for the firm, while 31% of the firms disagree. Of those 31%, which corresponds to four firms, one pro-duces 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 [29].

4.5. Bargaining power of suppliers

In table 4 are presented the results regarding the Bargaining power of Suppliers force.

Table 4. Questionnaire results regarding "Bargaining power of suppliers" force

Key Factor	Factor	Results
Supply Chain Decentralization	Supplier's integration in firms' operations	31% reactive and 38% ad-hoc communication
Shortening of Supply Chains		8% sharing data and repositories
		8% fully integrated information systems
Vertical Integration	Organisational alignment	62% find it easy to align production process with suppliers
General Aspects		62% disagree that suppliers have easiness in changing prices
		77% agree that a small number of suppliers supply a large proportion of raw materials sector
		85% agree that competition is affected by the bargaining power of suppliers
		69% agree that firms in this sector can easily change suppliers

Regarding decentralization and shortening of supply chains, these two factors are analysed 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 organisation. The only firm that acknowledges to be fully integrated with the suppliers, reports that benefits from supply chain simplification as result of AM technology usage. 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.

Concerning vertical integration, the intent is to test the feasibility of vertical integration. For that firms were asked to express an opinion about the ability of the suppliers to align themselves with their productive process. As depicted in Table 3, most of the participating firms agree that for their suppliers would be easy to align with their production process.

Lastly, to evaluate the bargaining power of the suppliers, in general, firms were asked to express an opinion regarding suppliers regarding some statements about suppliers' capacity to raise prices, market concentration, influence over competition and supplier change procedure.

Most of the participating firms disagree that is easy for their suppliers to raise prices or reduce product quality. 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.

4.6. Rivalry among the existing competitors

Table 5 presents the results for Rivalry among the existing competitor's force. To understand how these factors influence this force, firms were asked to give their opinion about some statements. The intent is to understand how competition works between firms using AM, the role of IPR in competition and if AM users benefit or not from technological advances.

Table 5. Questionnaire results regarding "Rivalry among the existing competitors" force

Key Factor	Results
Rivalry as a new sector	54% agree that competitiveness of AM firms is intense
	54% agree that there is a wide variety of competitors that use AM
	77% agree that the use of AM allows firms to serve different markets

Globalization	62% agree that changes in own strategy affect others
Intellectual Property Rights (IPR)	69% agree that the lack of IPR regulations is an opportunity for firms
More access to information and knowledge	92% disagree that technological advancement allows better access to knowledge about AM

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. These conclusions are also true for the existence of a wide variety of competitors using AM, as both are consequence of the same, plus the advances and improvements achieved in recent years.

As regard to the ability of serving different markets, 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.

It is also possible to conclude from Table 4 that most of the participating firms act in sectors where changes in their strategy affect the competing firms. 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 IPR, 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.

5. Conclusions

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.

In the perspective of the “Threat of new entrants”, firms are characterized for having low capability to capture AM talent and knowledge, being vulnerable to competitors who possess highly skilled workforce and valuable knowledge assets. Knowledge is still a barrier to implement AM. Firms capitalize on extant knowledge in a small number of workers and recruiting AM professionals is difficult. AM implementation also requires high capital investments. Though, only 30% of the inquired firms spent above 10,000 euros in AM, which can be explained by firms finding difficult to capitalize on the investment when compared with conventional manufacturing. Regarding EPR, only 23% of the firms track the entire product life cycle, being mostly from automotive sector. This constitutes a barrier for EPR implementation. Lastly, 77% of the inquired firms don’t use any kind of IPR protection, which is an opportunity for more competitors in the sector. In future, IPR regulation and digital tracking (e.g. using Blockchain) may be crucial to ensure IPR protection.

Regarding the "Bargaining power of customers”, since few firms have some kind of after-sales service (in table 2 the maximum value for this key factor is 54%), there is opportunity for customers have higher bargaining power, being able to repair their own products in the future. Regarding the threat of “prosumerism” as a competing force, there is no consensus. 31% of firms agreed with the idea, but 38% disagreed. The rest don’t have an opinion in the matter.

In the perspective of the "Threat of substitutes" force, nearly more than half the companies do not believe that their products are easily replaced. Though, 85 % feel pressured to develop cheaper alternatives. On the perspective of swap ‘n’ go providers, firms don’t consider this a threat. Moreover, it is noteworthy that most companies do not consider AM a good method to produce standard products, which reveals that this technology is still in maturing process but far from becoming an option to compete with conventional manufacturing.

Concerning "Bargaining power of suppliers" force, the major incidence of agreement falls on factors such as vertical integration by suppliers as a reality, the existence of a small group of suppliers providing the sectors' needs and that those suppliers strongly influence sectors competition. That contrasts, however, with the key factors “SC decentralization” and “shortening of SCs”. Results show that few companies have decentralized tasks, based on the use of AM. Only 1 company in a total of 13 was able to allocate tasks to partners in the SC.

Lastly as regard to "Rivalry among the existing competitors", 54% of the firms agree that competition of AM is intense, and that there is a wide variety of competitors using AM. That may be explained by the crescent evolution of AM and also that early adopters of AM are now starting to capitalize their knowledge. However, technological evolution solely is not guarantee that firms are able to apply AM. On this regard, 92% of the firms revealed difficulties in accessing AM knowledge.

In summary, despite the many developments in AM, there are still barriers to overcome to successfully implement AM. Knowledge in AM, specifically in the form of well-trained and skilled employees is lacking in Portuguese industry. Also, although there are several maturity models and roadmaps for Industry 4.0, there aren’t any knowledge models to deploy AM technology. Regarding capital investments, there is still low investment because successful business models are still scarce. IPR protection it is also an issue. While in industry there is regulation (e.g. patents, agreements, etc.), with the ease to exchange digital over the internet, contents may require IPR protection for consumers (specifically for “prosumers”). Initiatives like EUR and the manufacturing democratization may shape the future of AM, where consumers play a part in the production process.

With the application of the adapted Five Forces Model for AM it was possible to identify key aspects that firms need to overcome to obtain a successful implementation and capitalization of AM. The method allowed successfully to identify the advantages and shortcomings in each model perspective. This approach is unique in AM literature and, in future, further research will concentrate in developing the model as a tool for companies to self-asses.

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