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Understanding how Additive Manufacturing influences organizations' strategy in knowledge economy

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Abstract

Industry 4.0 constituted a trigger to a new phase in the Industrial Revolution, heavily focused in 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, is implicating changes on the labor market, as new jobs strongly rely on knowledge-intensive activities. This is forcing organizations to rethink their way to operate, since markets are getting even more competitive and susceptible to greater volatility. Herewith organizations are resorting to AM as way to strengthen competitive position, as this technology allows to seize new opportunities. As response to that, this paper presents an industry analysis to AM based on Porter's Five forces model, where forces such as threat of new entrants, bargaining power of customers, threat of substitutes, bargaining power of suppliers and rivalry among the existent competitors will be discussed under a knowledge perspective. The compiled evidence show that AM industry will plausibly suffer from a high rivalry in the next few years, as consequence of the increased power of customers and suppliers, low entry barriers for new entrants and due to pressures for a more sustainable society. Although these forces will not be totally controllable, organizations can plan their business strategy according to the knowledge they have on them. This type of approach will allow organizations to influence these forces more closely and at the same time to predict possible scenarios, identify tendencies and map the sector. In the present paper is proposed a conceptual model based on Porter's five forces to analyze the impact of AM on firms' strategy. For future development this model will be extended to organizations operating with AM in Portugal for validating its practical applicability, which will be performed through questionnaire and/or case study.

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

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1. Introduction

The constant technological evolution that the world has been witnessing in the past few decades is imposing a high pace at the global markets [1]. 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 [2]. As consequence, customers are getting more demanding and with access to a diversified range of offer, which lends to markets greater competitiveness and volatility. This volatility stems from the fact that customers start to detain 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 [3]. Therefore, organizations need to be dynamic and always looking for ways to strength their market position, and consequently, achieve advantage over their competitors [4].

As globalization and disruptive technologies continue to gain force, the context adjacent to industries is becoming very distinct from the one Porter studied and by 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 [5]. 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 table [6]. At this stage AM technology 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 evidences are still scarce, knowledge and assessment models are crucial [6]. To contribute to cover this gap, this article summarizes some fundamental concepts of additive manufacturing business models contemplating knowledge economy and structural industrial analysis by M. Porter. Hence, to understand the role that this technology will take in this digital era, this paper presents an industry analysis based on Porter's five forces model for emerging business models in the field of additive manufacturing, under a knowledge perspective. This perspective is taken since knowledge is one of the most critical assets nowadays, and thus will play a powerful role, in the sense that is through the right exploitation and application of it - together with these new technologies, i.e., AM - that organizations will be able to achieve competitive advantage over their rivals [7].

2. State of the art

As this paper 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 brief description of the changes that knowledge economy brought.

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, environment, production systems and machines, among others [8]. 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 [9].

In this context, Additive Manufacturing 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's or reverse engineering techniques [10]. Although the technology itself is old, its 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 [11].

In the context of Industry 4.0, AM emerges as a key technology to this digitalized and smart era enabling a fast development of products through an additive process instead of the usual subtractive or molding forms of traditional manufacturing [6].

2.2. 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 barriers and impacts that are found in literature. The term smart factory appears as a key concept of this new era and it is empowered by AM, AI, IoT, AR, Big Data, Machine Learning, Blockchain and Robotics [12].

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". This novel concept of manufacturing leaves underlined the idea of Cyber-Physical Systems (CPS) as way to manage and leverage the connection between physical factory floor and computational resources [6], [12].

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 as better satisfy them [13].

In general, the current stages of implementing AM in production process can be summarized in three main parts [14]:

- Creation of the model/ reverse engineering,
- Printing
- And finishing process.

Regarding smart factories the essence remains the same, although the production process is more elaborated because of the inherent interaction between the technologies above mentioned. First, it is 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 [15].

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 [16]. The technology beyond these changes is IoT, supported by Big Data, who monitors production in real-time [6]. Since manufacturing is 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. These collaborative robots, also known as Cobots, support smart inspection and corrective actions for quality control systems, by controlling and identifying process deviations [17]. Relatively to AR, this one is used to assist maintenance workers with maintenance and repairing equipment, like 3D printers [15] or for structural monitoring in high-level industrial fields as aerospace [18]. Finally, AI takes part in this process by scheduling the running operations.

Joining all those technologies increase processes' reliability and effectiveness, making viable the introduction of additive manufacturing in industries such as aeronautic or health [19].

2.3. Structural Analysis of Industry

Competition is inherent to any business environment; hence, the way organizations cope with it determines their failure or success in the market. On top of that, Professor Michael Porter also noticed that some industries were more profitable than others, which led to his published works entitled "How competitive forces shape strategy" and "Competitive Strategy"[5].

In the article "How competitive forces shape strategy" an analytical framework was proposed. This framework goal is to assist in the process of identification of critical factors as well as an effective strategic positioning that best suits the organization, i.e., that allows directing efforts in those aspects in need [5]. Although this framework has been proposed in 1979/1980 by M. Porter with the advent of globalization and arrival of disruptive technologies the need

to outstand competitor's performance became even more a pressure point to many organizations. By virtue of that, it is imperative that firms choose wisely their competitive strategy, i.e., how to offer added value to their customers – as process innovation or culture ideals. Thus, competitive advantage is achieved through the organizations ability to create added value. Value can be defined as the perceived utility that customers are willing to pay in detriment of a specific good or service, i.e., when willingness of the buyers exceeds the firm's cost [5].

Also implicit to the choice of a competitive strategy is the considered industry attractiveness, since it relays on how much profitable it can be. Nonetheless, 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 [5]. To prevent that, a trend analysis of the industry it is important when in it comes to define a strategy.

This analysis of the industry can be done using Porter's Five Forces model. The competitive forces that contemplates Porter's analysis are the threat of new entrants, the threat of substitutes, the bargaining power of suppliers, the bargaining power of customers and the rivalry among the existing competitors [5]. These forces determine the ability of an organization to prosper in a specific context, by constraining, or not, their capacity in retain earnings superior to the needed investment. These forces are dynamic, since they change as the industry evolve and vary from industry to industry, which shows that their intensity is a function of the elements that compose industry structure, such as economic and technical characteristics [5]. Nonetheless, they are not only influenced by intrinsic aspects of the industry but also by the macroenvironment factors such as technology and innovation, government policies and the existence of complementary products and services- what demonstrates that the main question do not rest just in picking the right industry [5].

Now addressing the forces that contemplate "Porter's Five Forces Model"- as referred in literature - "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 economies of scale, capital requirements, switching costs, access to distribution and necessary inputs. So, if the entry barriers are high, newcomers have more difficulty in penetrating that market and, consequently, that contributes to higher profitability to incumbent firms [5].

"The bargaining power of buyers" can also establish a cap on industry profitability, i.e., if buyers detain much power in negotiation leverage, they can capture more value by exerting pressure to force down prices. 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 and if the industry's product is too profitable, in some cases, an opportunity to backward integration can threaten incumbent firms [5].

"The bargaining power of suppliers" – which is the flip side of powerful customers – is more intensive if supplier's concentration is higher than the industry it sells to, when associated switching costs are high for firms, when suppliers serve many industries, when offered products are differentiated and does not exist any substitute for what their provide. Thus, when supplier side has more leverage on negotiation it affects industry potential profit and may even threaten incumbent firms with forward integration fitting in as additional competitors [5].

Relatively to "Threat of substitutes" is important to first explain that what characterize two goods as substitutes is the fact that they perform the same or similar function and the existence of a strong influence over pricing strategy between industry's product or services. Hence this places a ceiling on prices which means that the appearance of substitute products/ services affects industry profitability. Technological changes can also have major impact in this aspect since unseeingly improvements in unrelated industries can suddenly show up as a substitute product [5].

Lastly the pressure exerted by all the previous forces conferees a certain degree of intensity in industry competition, known in literature as "Rivalry among the existing competitors" force. The intensity of this force is determined by industry growth, exist barriers, fixed costs, diversity of competitors as well as the size and power that each competitor has. Similar to what happens with the other forces, the intensity of rivalry can have a significant impact in industry profitability [5]. That said, it allows to point out that industry leaders carry the burden of having greater impact on industry structure, due to their size and consequently influence.

2.4. Knowledge Economy

The advent of globalization and emergence of disruptive technologies are contributing to the setting of new industries, which is imposing higher rivalry tensions [13]. On the other hand, the exploitation of disruptive technologies, such as AM, enables a faster response to customer needs leading to the strengthening of rivalry [1].

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 [7]. Thereby, knowledge became an increasingly relevant asset for organizations which gave space to transit from an economy based on material resources to an economy driven by knowledge [20]. The material-based economy is dependent on assembly lines and where physical inputs are the primary source for production and economic development [21]. On the contrary, in the knowledge-based economy, the economy is driven by decentralized information and relies on knowledge creation and dissemination [21].

This shift from an industrial economy involved changes on the labor market, i.e., a higher level of education is needed, since the new job strongly relies on knowledge-intensive activities [20]. The raw material of 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) [22]. In result, ICT are now more essential than just a supportive mean to assess the competitive forces as portraited with Porter's model [3].

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 allows organizations to increase their agility when it comes to respond to those events [22].

3. Conceptual model

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 [23]. 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 [24]. The promises that continuous products can bring 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 [24]. 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 [24]. This is driven by the availability on lifespan information of product that becomes available since AM technology brings closer the manufacturer and consumer due to co-creation and consumer-centric production paradigm [25].

So as mindsets have been changing and new realities are imposed, potential business and production models that support the type of product described above are, for example, Product Service Systems (PSS) and Distributed Manufacturing Systems (DMS). 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 focus on the purchase of utility instead of the product itself delivering customers' needs and reducing material and energy requirements [26]. 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 [27].

Conversely, DMS is a decentralized manufacturing system that makes use of ICT to bring products close to the customer [28]. 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 fulfill local needs [28]. 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, diminish of logistic cost, democratization of design, regionalism and authenticity [28].

Figure 1 schematizes Porter's five forces model applied to AM. In the next subsections will be explained each of these forces and the respective shaping factors.

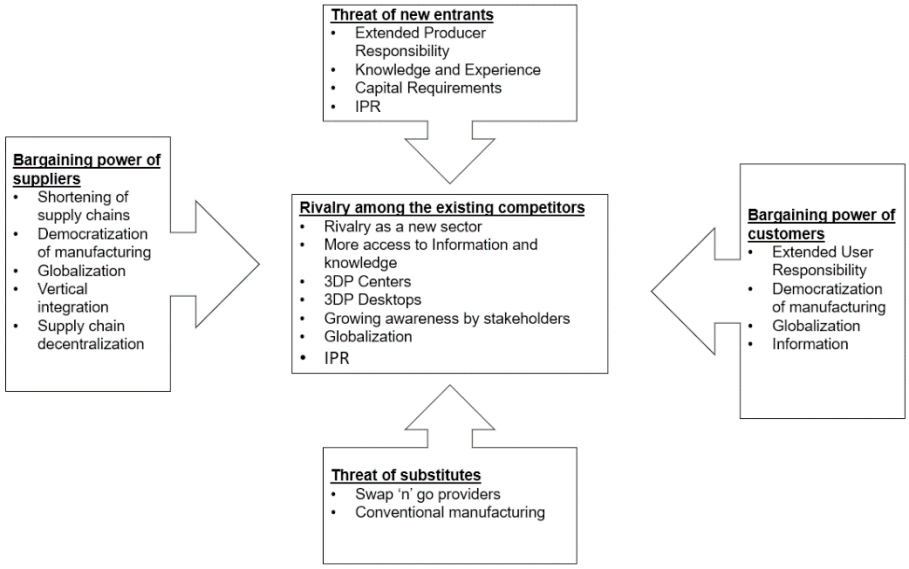

Figure 1- Porter's five forces model applied to Additive Manufacturing in a knowledge economy

3.1. "Threat of new entrants"

Starting with the "Threat of new entrants" a concept that will play a significant role is 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(…)" [29]. This entails that the producers need to have resources to deal with the product at end of lifecycle, either as workforce capacity, space and/or financial funds [24]. This can show up as barrier to small producers that may want to enter but do not have already the infrastructure needed to accomplish that. Another factor influencing this force is the knowledge seized by organizations about AM. As mentioned earlier, this technology has its roots in 1980 though the growth regarding its use has only started in the past decade. This gives to early adopters an advantage, in the sense that they know the market better. It also becomes crucial the employment of qualified workforce since the job now requires understanding and make use of specialized software as well as considerable knowledge in engineering design [23], [25]. Regarding costs, the use of AM will reduce upfront investments due to its free forming nature [2], [23]. Thus, the capital requirements needed concern chiefly with software, 3D prints and specialized workforce, either as training or employment.

Intellectual Property Rights (IPR) will also play an important role when it comes to the threat of new entries. 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. This would give a huge advantage to the organization in question, and consequently, raise the entry barriers [30]. Also, as 3D printers became abundant, and no legal systems are available for this technology for protecting intellectual properties rights products designs can be widely distributed and identical products manufactured without the approval of the owner. The dichotomy around intellectual property rights is that depending on the perspective, they can be an opportunity or a challenge for new entrants [25].

Lastly, but not least universities will 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 business 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 [23]. For this to happen, universities will have to go beyond those activities described above- that has been their mission – and engage with societal needs and market demands, so called universities third mission [23]. This concept of a third mission emphasis that communication between distinct parties is crucial for innovation and

economic development in a knowledge society. It is out of that interaction that is possible to reinvent institutional and social formats for production, exchange and application of knowledge [23]. An example of it is the cooperation between universities and Fab Labs, that are workshops offering access to personal digital fabrication and knowledge.

3.2. "Bargaining power of Customers"

Regarding the "Bargaining power of Customers" this is a force that has been greatly affected by the progresses made in ICT and the development of new technologies during the last years. On one hand, customers have now a huge amount of available information. This 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. All of this is only possible due to the growth of e-commerce that shifted the power to end consumers and allowed them to buy globally [3]. On top of that, 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 [25]. Prosumers can be described as consumers that produce products primarily for his 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 manufactures [31].

Another factor that can increase the strength of this force is the introduction of a "Extended User Responsibility" legislation. As products are thought to have extended life cycles, the introduction of a legislation that allows individuals to repair their own products without infringe 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 also be enhanced by "prosumerism" [24].

3.3. "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. On one hand, the modularity facet of those type of products empowers the appearance of swap 'n' go providers. A swap 'n' go providers is a qualified manufacturer that is certified to make design upgrades or repairs to the product allowing individuals to not 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 functional requirement, for example. Then the product is printed and installed [24]. On the other hand, AM cannot entirely compete with conventional manufacturing in mass production field, e.g., standard products which constitute a high threat depending on which industry the organization operates in [32].

3.4. "Bargaining power of suppliers"

Concerning "Bargaining power of suppliers", one of the most popular consequence of AM technology, that 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) both by empowering the shift from physical to digital inventory since, for instance, it is easier for data files to travel than tangible products [33], [34]. The decentralization of SCs is threating suppliers' power as "glocalization" is placing manufacture closer to the final customer. This phenomenon traduces in fewer stages involved, compared to traditional SC, since less packaging, transportation and warehousing is needed [33]. Furthermore, as setups procedures are almost inexistent and processes can be automated and monitored at distance, less people become needed. However, although AM is capable of ease, for example, the existing dependence on component suppliers the lack of competition existent on material and information technology (IT) suppliers may balance this force [34]. 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 [33]. 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 [35].

3.5. "Rivalry among the existing competitors"

Ultimately, the strength of "Rivalry among the existing competitors" depends on the pressure exerted by the above forces as much of the intensity with which companies compete and on which basis they compete. For instance, 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 considerable down given that AM has undergone an average growth of 27,4% over the previous 10 years [36]. Nonetheless, analysts are predicting that AM will have an economic impact of 550 billion US dollars a year by 2025 [37]. This indicates that AM market will presumably suffer from a high growth rate in the next few years.

AM revolution is also taking rivalry into a different degree of intensity as rivalry now can 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 produce only a specific product [33].

Also as stakeholders are getting more socially and environmentally conscious the demand for added-value products with extended lifecycles is becoming a reality [24]. This can inflict pressure on this force on account of globalization, i.e., 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. Furthermore, 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 [3].

Lastly, the increasing availability of 3D printing services, as Fab Labs or 3DP Centers, will potentially 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 understanding, 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 [25]. Therefore, is plausible that with AM industry rivalry will be intense [25].

4. **Conclusion**

The present paper demonstrates 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 the study of the economic aspects of this technology, for example as economic viability of the production, but also focus on the change's 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 businesses models which is the main goal of this work. Thus, the aim is 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. The key issue in this case concerns to the ability of assets to effectively manage the knowledge they hold so that the organization can extract its full potential, which ultimately leads to a reinforcement of the firm's economic position in the market. The proposed application of Porter's Five forces model to AM evidences that factors such as IPR, "Glocalization" and knowledge economy will have a preponderant role in this digitalized and smart era. Plausibly, these same factors will be the main responsible for the expected high rivalry tension within AM industry. The contribution that is expect 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 applied to AM in firms' strategy area.

For future development we will further extend this model to Portuguese organizations operating with this technology. The idea is to conduct qualitative research of the Portuguese industry using AM, through questionnaire and/or case study, to obtain an overview of the sector and validate the practical applicability of the developed model.

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