4th Industrial revolution impacts on business model: a detailed look in the high-tech industry

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1. Introduction

The goal of this paper is to investigate the transformation of the business model as consequence of the fourth industrial revolution (hereafter I40) in manufacturing industry focusing on the production chain relationship of small and medium enterprises (hereafter SMEs). I40 focuses on the role of digital technology in the creation of intelligent products and production processes and grasps the digital enhancement or even re-engineering of products and services. Specifically, the fourth industrial revolution involves a deep transformation in the way production takes place and traditional manufacturing plants are replaced by smart factories based on the communication between humans, machines and products through the implementation of Cyber Physical Systems (hereafter CPS) for industrial production. CPS are networks of microcomputers, sensors, and actuators that can be embedded in materials, devices or machines, and are connected through the internet along the value chain (Porter and Heppelmann, 2014; Rudtsch, Gausemeier, Gesing, Mittag, & Peter, 2014). Thus, today (before than tomorrow) firms in the manufacturing industry should cope with the need of rapid product development, flexible production as well as complex and global environments. Based on this evidence, we aim to investigate if and how the challenge offered by the I40 calls for new business model to improve value creation to the customer.
The academic investigation into I40 extensively focuses on large enterprises (Arnold, Kiel & Voigt, 2016; Radziwon, Bilberg, Bogers & Madsen, 2014); only marginally on

SMEs (Schmidt, Möhring, Härting, Reichstein, Neumaier & Jozinović, 2015). We observed how many large firms act as suppliers to SMEs and have SMEs as suppliers. Thus, it is important to consider how SMEs implement I40 and how the latter impacts on industrial value creation considering their role in the value chain.

Based on the arguments above, the present paper aims to provide answers to the following four research questions:

RQ1: How do manufacturing SMEs perceive the I40 phenomenon?

RQ2: How do manufacturing SMEs innovate their business models because of I40?

RQ3: How do manufacturing SMEs behave with their suppliers because of I40?

RQ4: How do manufacturing SMEs behave with their customers because of I40?

To achieve these expected results a qualitative method will be applied, conducting an explorative case study following in-depth interviews to entrepreneurs and managers operating in the high-tech industry for data gathering. We focus on the specific case of high tech industry (hereafter HT) because it is digitalized since '80, while not HT industry is typically analogical and I40 can just improve digitalization (e.g. foundry, rod, die). The research is organized in three main phases. First, we present the theoretical background on business model focusing on the production chain relationships in the context of I40. Second, we provide a framework for its analysis, and third we present the empirical results to identify the implications and conclusions of our case study.

2. Theoretical background

2.1 Industry 4.0

Industry 4.0 is a term used to refer to the developmental process in the manufacturing process, including also the production chain. The term Industry 4.0 was first publicly introduced in 2011 as *Industrie 4.0* by a group of representatives from different fields (such as business, politics, and academia) under an initiative to enhance the German competitiveness in the manufacturing industry. The German Federal Government adopted the idea in its High-Tech Strategy for 2020. Subsequently, a Working Group was formed to further advise on the implementation of Industry 4.0.

To understand how Industry 4.0 became the fourth revolution, we need to look therefore at the evolution of manufacturing and the industrial sector and see how it is different compare to the past three ones. Moreover, we need to consider that revolutions suppose an acceleration of the rate of change. But how much does the rate should change for it to be considered a *revolution*? We should consider that technological change *per se* is not sufficient to identify an *industrial revolution*. One key point is that this change has to be permanent and it should lead to a new economic trajectory. The second relevant aspect is the link between technological change and organization. Mokyr says that *a real industrial revolution consists not just of technological innovations but of such innovations that make an impact at the level of industrial organization* (Mokyr, 1997, p.35).

The First Industrial Revolution (1760-1840)
It took place in Britain and introduced machines into production. Manual production was abandoned in favor of the use of steam-powered engines and water as a source of power, and we assisted at change in the organization of production from the cottage industry to real manufacturing plants.

The Second Industrial Revolution (1870-1914)
It introduced pre-existing systems such as telegraphs and railroads into industries. The most relevant change was the introduction of mass production as a primary means to production in general thanks to the electrification of factories contributed hugely to production rates. The mass production of steel helped introduce railways into the system. Such revolutionary approaches to industry were put to an end with the start of World War I.

The Third Industrial Revolution (1950-1970)
It came about the change from analog and mechanical systems to digital ones and it is called as the digital revolutions. The third revolution is a direct result of the huge development in computers and information and communication technology that reduced dramatically the costs of collecting information and coordinating activities within the firm and with outside partners. One implication of this revolution has been a strong trend toward deverticalization and outsourcing.

The Fourth Revolution
According to experts from industry and research, the upcoming industrial revolution will be triggered by the Internet, which allows communication between humans as well as machines in CPS throughout large networks. It introduces customized and flexible mass production technologies so, again, a new interaction between technological change and industrial organization occur. Machines will operate independently or cooperate with humans in creating a customer-oriented production field that constantly works on maintaining itself. The machine rather becomes an independent entity that can collect data, analyze it, and advise upon it. The idea behind Industry 4.0 is to create a social network where machines can communicate with each other, called the Internet of Things and with people, called the Internet of People. Thus, machines can communicate with each other and with the manufacturers to create Cyber Physical Production System. Machines collect live data, analyze them, and even make decisions based upon them.

2.2 Business model
Over the last 5 years, business model research has been an area of lively discussion and inquiry, but there is not yet a general accepted definition (Massa, Tucci & Afuah, 2017). Business model (hereafter BM) shows how the management of the firm designs and hypotheses about what and how customers want (i.e. value offer), how the firm can organize itself to best meet these needs (i.e. value creation), get paid for doing so, and make a profit (i.e. value capture) (Baden-Fuller and Haefliger, 2013; Teece, 2010). The

BM is made of different components (i.e. revenue, cost, partnerships) (Osterwalder, Pigneur and Tucci, 2005); the main is the value proposition that describes the drivers of customer value as well as the unique features that the firm's offering to capture the value (Bouncken and Fredrich, 2016). Value capture (that includes the structure of the costs and the formula of the revenue) defines how firms are compensated by customers (Massa et al., 2017).

From a strategic management perspective, the BM concept generates an understanding of how organizations can use I40 to provide suitable value offers (and pricing models) to their customers. Considering that the BM concept is intrinsically linked to the exploitation of opportunities (DaSilva and Trkman, 2014; George and Bock, 2011), such as the ones brought by novel technologies (Spieth and Schneider, 2016), the new contingency creates from the I40 calls for BM that have the capacity to collect data from the customer side in order to deliver products better tailored, priced and delivered to customer or segment needs along the entire lifecycle of the product (Kagermann, Helbig, Hellinger & Wahlster, 2013; Porter and Heppelmann, 2014). In this process, the relationships inside the production chain are crucial. I40 offers new technologies to make interactions and the BM can originate new solutions in one of the three business model elements: value creation, value offer and value capture. The analysis of those dimensions of business model are highly interconnected, so the innovation in one element leads to changes of varying degrees in the other two (Zott and Amit, 2010). Our point of observations is the role of the interactions inside the production chain on the variation of one of those elements.

3. Methodology

3.1 Research design and applicability: deciding to use a case study approach

Qualitative research remains a challenge within I40 business management and calls for this kind of research are frequent. A first reason is that I40 requires more explanatory and theory generating research. Qualitative method in fact, goes beyond the measurement of observable and tries to understand the meaning and beliefs underling action by answering complex issue that are typical for the fourth industrial revolution.

Qualitative research generally attempts to generate, elaborate, test or induce radical change in theory (Lee, Mitchell, and Sablynski, 1999; Yin, 1984, 2003). In our case, the area of research is relatively less known, and we are engaged in theory-building and theory elaboration types of research which need to answer *how* and *why* questions (Eisenhardt, 1989; Ghauri and Grønhaug, 2002). As such, we make the choice of using case study because it is expected to advance our understanding of the research phenomenon rather than generalization. We want to investigate the relevance of I40 and its associated research streams. The research design is a single-case study but involve numerous level of analysis. It has been preferred to single level case to create more theory-driven variance and divergence in the data that facilitates analytic induction (Pauwels and Matthyssens, 2004).

3.2 Selecting case

A researcher can investigate I40 at different level (i.e. workers, firm, industry, and ecosystem), in this paper the research design involves the study of one case as the unit of analysis is the production chain and the relationship among its actors. The central firm is a discrete and easily detected subject that can be analyzed both as isolate experience in the production chain and as part of a comprehensive experience of the interviewed firm (i.e. the analyzed firm, its suppliers and customers).

Our sampled firm (and its suppliers and clients) reflects the selection of specific case to induce theory. We selected a high-tech firm that starts produce in '80, SEI Laser. We choose laser technology because it is, among other, an excellent way to reach digital production. Thanks to photonics I40 simulation, digital design and real production processes are growing ever closer together. As such, laser technology is the driving force to an increasing extent: laser tool, cut, solder weld and perforate. Lasers harden steel and process metals, plastics, glass, diamonds, wood, ceramics and many other materials with extreme precision, flexibility and speed. The concentrated light works without contact and does not introduce any mechanical forces into the processes and, conversely, is not affected by wear and tear. In other word, the material is processed and removed atom by atom and, translated in the digital production world of I40, this means material processing pixel by pixel.

As suggested by Lee et al. (1999) there is no ideal number of cases to identify suppliers and customers' specificities and we stop adding cases when no or little incremental learning would occur from more data as we are observing phenomena seen before (i.e. theoretical saturation). The final setting is seven firms in three different point of production chain.

3.3 Analyzing case study

As in typical inductive research, we synthesize case, and to avoid errors arising from halo effects and other interpretation biases (Strauss & Corbin, 1998), the transcribed notes were used by a subset of team members (including at least one team member not present at the interviews) to establish a preliminary framework. We followed an iterative process of marking quotes and concepts and reviewing our notes to identify patterns or themes across interviewees.

The first step of our analysis is writing firm's individual case history by writing chronologies of the organization (Eisenhardt and Graebner, 2007). So, we can track the phenomenon of I40 as it is, an evolution or disruptive process over time. In the second step the data are rearranged into a conceptual order searching for common and conflicting themes. In the third step, we made cross case analysis trough supplier, firm and customers as suggested by Eisenhardt (1989) and Miles and Huberman (1994) to discover regularities and patterns. We also analyze data by various sources. At the end of the third step, theoretical construct and tentative propositions (i.e. a framework) are developed both considering existing literature but also looking for unexpected process.

3.4 Data sources and collection

Our study involves data collection through multiple sources that are: in-depth interviews and written reports (e.g. financial reports, archives, press, budget, market and competition reports).

The primary rich source of data is face to face in depth semi-structured interviews that facilitated a free expression of the informants' ideas. We plan the interviews with multiple person within a company: firm level executives (e.g. the entrepreneur/founder, vice president, chief executive officer) and at least one member of the management team responsible for R&D. To limit subject bias, we adopt a courtroom procedure (Eisenhardt, 1989) and we asked interviewed person to step through a timeline of facts. Only at a second step we reviewed the chronology and we asked informants about I40 through both direct and indirect questions (Bingham and Eisenhardt, 2011). With at least one of the authors present, team members were encouraged to correct facts pertaining to the interviews such as timing or outcomes but not why certain events transpired. This technique helped ascertain the facts of each case but allowed freedom in causal attributions.

Questionnaires supporting semi-structured interviews include questions that investigate on both quantitative description and qualitative evaluation of the features of I40. The triangulation, made possible by multiple data collection methods, on the one side provide stronger substantiation of constructs and hypothesis (Campbell and Fiske, 1959) and, on the another one, compensate the weaknesses in each single data collection methods by the counterbalancing strengths of another source (Jick, 1979). It was therefore possible to compare information obtained from interviews within the same firm and written records (i.e. financial and technical reports, archives, budget, market and competition reports). In fact, although written records are not our study's main source of data, they can effectively confirm, supplement, or elaborate upon one's more primary information (Lee et al., 1999). Moreover, the combination of both qualitative and quantitative can be highly synergistic because if on the one the side qualitative data (i.e. interviews) are necessary for understanding the rationale, on the other side quantitative data can reveal relationship which may be not salient to the researcher or can keep researcher from been carried away by false impressions in interview (Eisenhardt, 1989).

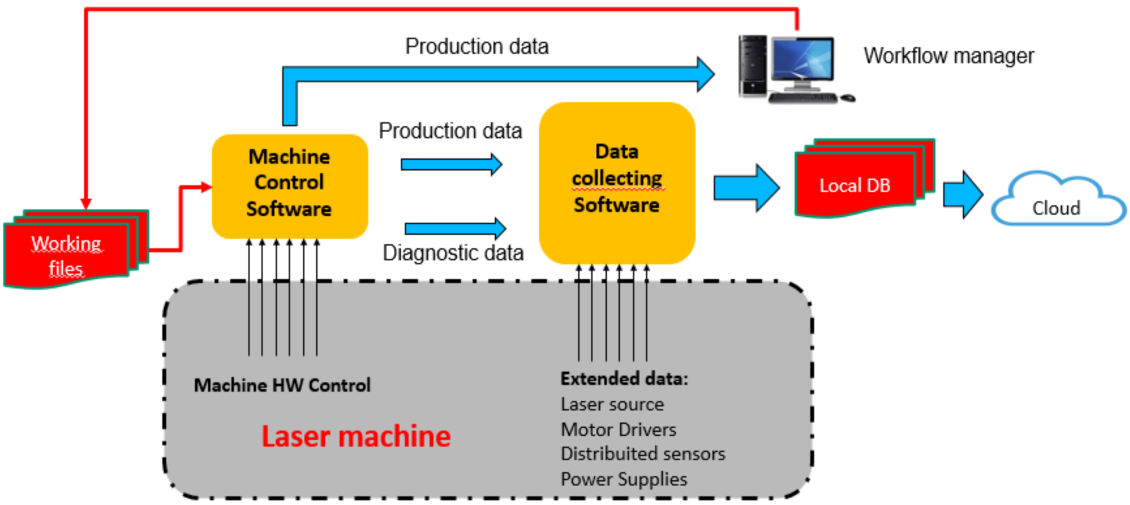
As previously stated, because firms may differ in their capability development based on position in the production chain of a HT industry, we selected firms representing each position in the entire chain. Overall, we collected data from seven semi-structured interviews (i.e. SEI Laser, three suppliers and three customers).

4. Results

4.1 Preliminary finding: industry and firm description

Since 1982 SEI Laser has been one of the most dynamic and innovative companies in the world of laser technology. Due to the complete range of laser systems developed by its R&D department, it can satisfy the application needs of customers (i.e. value offer) in both vertical and horizontal markets, including: lighting, visual communication, graphic arts, paper converting, labelling, flexible packaging, folding carton, fashion, interior design, furnishing, automotive, engineering and electronics. All SEI Laser systems use ICARO proprietary software which operates on Windows™ platform, making them easy to interface with the most evolved CAD-CAM versions on the market. SEI Laser has many prestigious customers and industrial partners who it assists with in-depth knowledge giving them innovative solutions which are often specific, and which give significant performances as far as cost, efficiency and quality of the final, generating value creation. For example, the solutions for the digital converters are represented by highly-performing systems, a philosophy of modularity on flexible, expandable and upgradable platforms, they can be suitable for different production needs with commercial, labeling and packaging solutions. Thanks to its technology, the converter has revolutionized his chances of growth and development: let's consider the laser as a digital instrument in a modern production process where the *web to market* is an easy goal to reach. SEI Laser does not only supply worldwide customers with products, but also offers integrated solutions specific to applications to help them find new opportunities for growth and development (i.e. value capture) (Figure 1).

Figure 1: Laser machines architecture

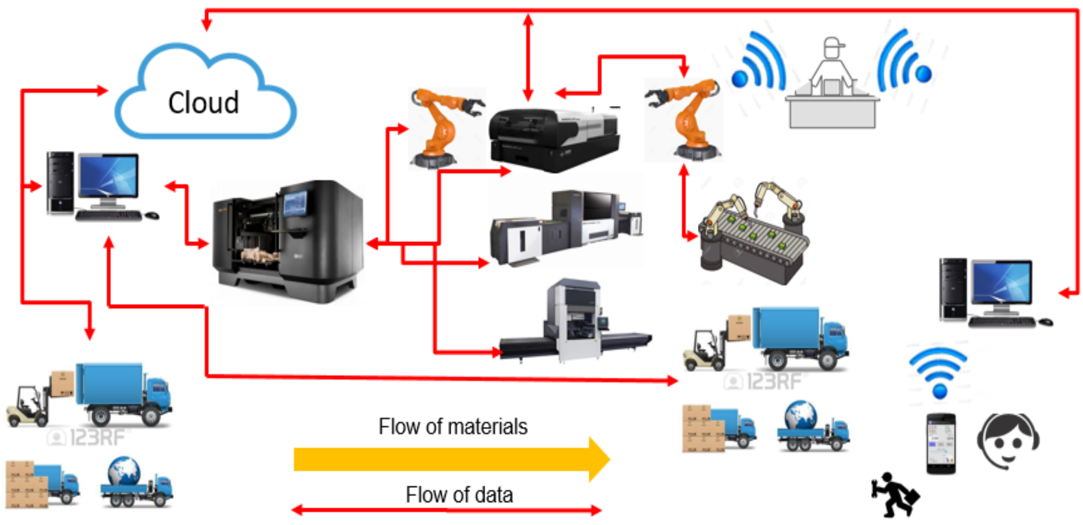


Source: SEI Laser, 2018

4.2 How SEI Laser perceived the I40 phenomenon and how it redefines its business model

Industry 4.0 is a technological evolution that crosses the productive sectors and dictates the new manufacturing needs, the flow of communication and the analysis of the process. It is not a specific product, but a new philosophy of integration and communication between machines, systems and computing cloud. SEI Laser has long time ago adopted technological choices that meet the new requirements. However, it is now necessary to carry out a new adaptation of the machines to enhance and make easily the access to the features required by the current technological trend (cit. Entrepreneur). (see Figure 2).

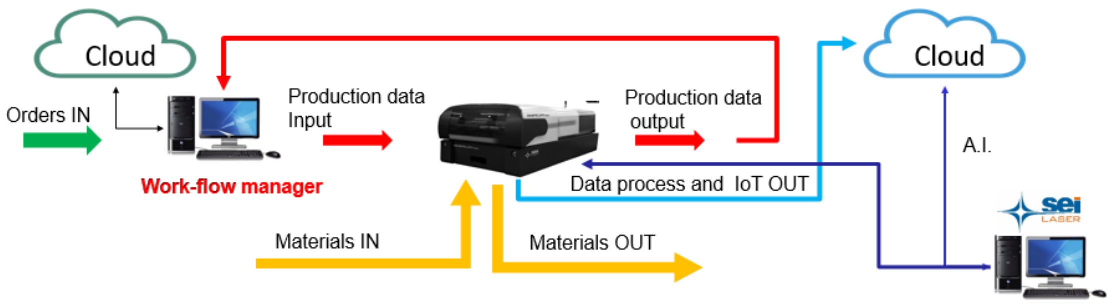
Figure 2: SEILaser's vision of fourth Industrial Revolution



Source: SEILaser, 2018

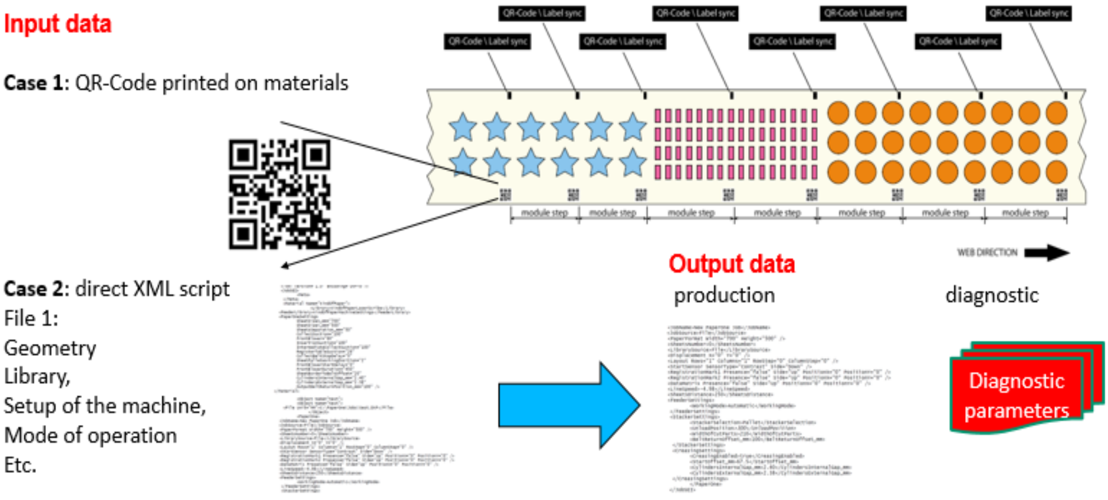
To SEI Laser, I40 means making machines capable of collecting and processing data without interruptions within the production chain with the clear aim of improving the assistance process even in remote and covering the needs of customers (i.e. value offer) (Figure 3 and 4).

Figure 3: Process digitalization



Source: SEI Laser, 2018

Figure 4: Workflow integration example



Source: SEI Laser, 2018

It is impossible to indicate a precise date in which the company started the reorganization of its business model, accepting the inputs coming from I40. It was a slow process started with the digitalization of the tools machine, at the beginning of the 90s. At that time, the management of the company understood the potential and the usefulness of making the machines more integrated along the network to the costumer (i.e. value capture) and, consequently, they started working to improve the design, oriented in the direction of having interconnected machines, able to save data and to do preventive analysis. The purpose of those activities was (and is) to create value for customers through the collection of data having the aim to improve customer assistance, even remotely (i.e. value offer). It was at that moment that the management started to think at the machines as an integral part of a production workflow able to dialogue with the production systems of multiple suppliers of the same client of the company. This change led to the need for new skills as testers or for doing assistance in the production process (i.e. value creation). Training courses on IT and data processing were carried out to adapt skills. Currently, both internal and external management of production are coherent with I40. Also, outside the company, SEI Laser operates coherently with I40 because the machines have access to the data of the actors present in the production chain.

These innovations have allowed SEI Laser to gain competitive positions compared to competitors who have continued to produce machines that are not integrated into the production workflow and therefore have not seized the opportunities of the I40 in a timely manner. SEI Laser today can be considered a leader regarding network and remote control of all the equipment (and this from the 2000s). Otherwise, for the aspects of using cloud and data analysis tools is still a follower. Summarizing, I40 implication and benefits for SEI Laser are identified in terms of value creation and value capture in Table 1.

Table 1: I40 implication and benefits for SEI Laser

VALUE CREATION	VALUE CAPTURE
High demanding accuracy	Productivity increasing up to 40%
New diagnostic capabilities	Improved technical capability to laser process
Flexi concept and working modes	Improved reliability
Extremely high geometrical accuracy and stability	New galvo tuning algorithms for improved dynamics
High demanding productivity	Higher focus resolution due to new motor for area selection
	Improved capabilities and performances due to new electronic board
	Remote cutting accuracy

Source: Our elaboration, 2018

4.3 How SEI Laser behaves with their suppliers in result of I40

The suppliers are classified into three categories: strategic, order-based and components. The strategic ones are located all over the world, the others two categories are chosen according to geographical proximity. The strategic supplier are the ones that provide the data needed to understand the progress of the entire sector in which they operate. The relationship with them was influences through the I40 because it allowed the acquisition of data in a direct, simple and complete way. Moreover, the language has been standardized and it allowed the company to acquire more information through shared protocols. For the ordered-based and component suppliers the I40 was not relevant.
Summarizing interviews, demonstrate that a non-disruptive process exists because SEI Laser has long since adopted technological choices that make existing machines already at least pre-arranged to the requirements of this new philosophy (i.e. I40). Finally, through the I40 the relationships with the suppliers have increased from a technical point of view as well as the interchange of technical reports making a change in the value creation and value offer of their BM.

4.4 How SEI Laser behaves with their customers in result of I40

SEI Laser customers are located all over the world. They are classifiable as follows:

1. Standards customer, not customized. They use laser machines to do different kinds of jobs, as cutting or engraving. In this case the impact of the I40 on the BM was not significant, even though preventive or remote maintenance was improved. In fact, those are customers for whom a profitable two-way information exchange has been created. At the present, the main problem is the lack of a common language, even if, thanks to the new technologies labelled I40, all the machines talk to each other. This is a new opportunity that will require new activities of brainstorming among all the actors in the supply chain with the aim of reaching a standard language for the productive sector and the suppliers chain.

2. Customers who place the machine in a highly digitized work flow. For those category of customers the I40 is decisive and has been disruptive as they had to create an I40 workflow. The choice of when to create the new work flow (i.e. innovation) depends on the production lines but it is in any case disruptive. For SEI Laser the BM changes.

3. Customers for which the machine is only partially inserted within the digitized process. This is an intermediate case, characterized by the peculiarities of both previous categories.

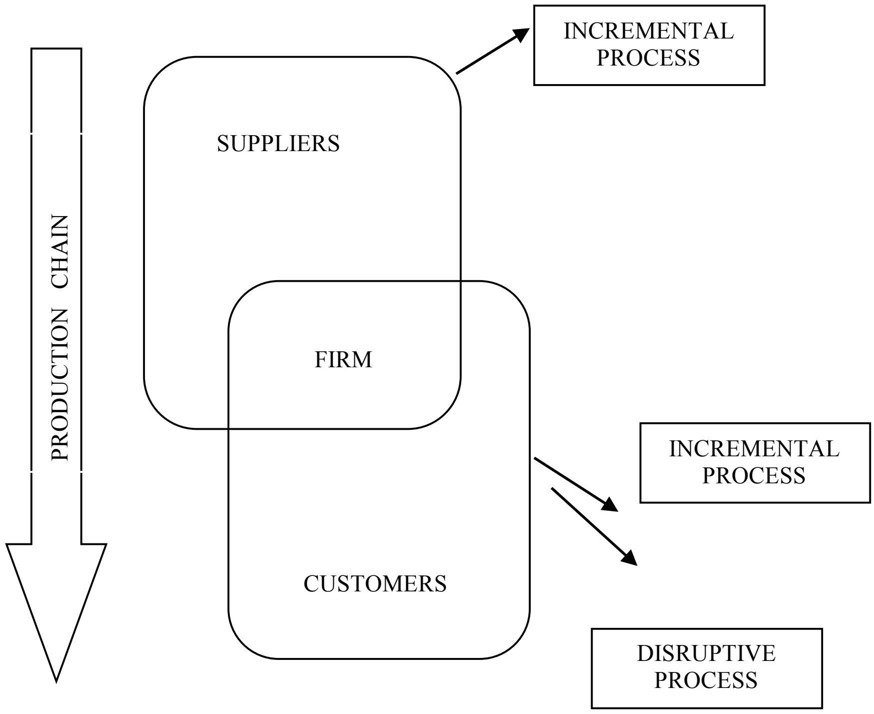
Finally, results from the interviews suggest that I40 is for a category a disruptive process, for other continuous, for other inexistent. In general, for I40 are true the following:

- is going through all the productive sectors, but not all the customers are ready to innovate and the face the challenge with I40 disruptively;
- dictates new functional, communicative and process analysis needs;
- is a new philosophy of integration and communication between: machines, systems of process (i.e. software), cloud data, cloud computing.

5. Discussion and conclusions

Previous literature states that I40 is expected to represent a paradigm change for business bearing strong effects in manufacturing processes and competitive advantage. Many authors say that such impact reveals in the disruption of traditional incumbents and in enabling the re-organization of production processes where applications of Information and Communication Technologies, Artificial Intelligence and Operational Technologies enable smart, self-organizing distributed system of factories. What we found is that this is not always true. We found that it depends on the position in the production chain. Therefore, there are firms face increasing pressure to change, while other one just faces adapting or making step by step evolution. In this second case, we argue that is not a really revolution, but a process, of course in high tech industry, that came from the past (Figure 5).

Figure 5: I40 evolution and disruption



Source: Our elaboration, 2018

The case study in high tech industry is a way to augment the awareness of scholars on the main implications of the transition to an Industry 4.0 paradigm along the entire production chain. The goal of our paper was to contribute with exploratory insights to a better understanding of how the fourth industrial revolution impact on how business models are being designed, implemented, and supported specifically in the high-tech industry. First, we identified the characteristics of the business model in such industry. Second, we hypotheses the impact of I40 on the business model following an explorative case. Our observation confirm that business model is critical for firm performance and needs to be adapted to the change especially in times of I40. To follow this goal, firms need to update their competences looking inside the relationships of the production chain.

Based on these evidences, we want to summarize the reasons why I40 is also an evolution process. Firms have been successfully supplying business partners with OEM systems for years. Where there were no opportunities to market directly, SEI Laser managed to build up strategic partnerships with important companies, to start a long-lasting profitable business by sharing its knowledge, strengths and presence within the market. It has also exploited synergies and achieved important goals which could not have been achieved in any other way. Trust, respect and mutual esteem have always gained us important long-term relationships which are constantly being renewed.

On the opposite side the reasons for why in terms of customers I40 is a disruptive process is that SEI's R&D team is a strategic internal resource, but also a support for customers

in the development of new products and processes. In the new scenario, innovation is a process that requires cooperation among different actors, both inside and outside the firm, including suppliers and customers. In Italy, like all over the world, the firm endeavors with constructive and cooperative spirit, to meet all customers' demands.
Suppliers can be distinguished between strategic and non-strategic ones; the first type are those who really provide and use a lot of data on the machinery and on the process, itself. Strategic suppliers do not need to be necessarily localized close to the producer, they may be, in fact, part of a worldwide network.

Another important aspect to consider is the necessity to acquire new competences and to invest in human capital. To use properly the new opportunities of the new methods of production the firm needs employees with high level of digital skills. This is one of the biggest challenge that companies need to face with the I40.

Our work is not deprived of limitations. First, future research need to look at other sectors to verify if the impact in term of disruptive level is the same. Second, we observed the slow change in the BM of the SEI Laser facing the suppliers and then the customers. This is strictly related to the characteristics of the product. Moreover, it is not generalizable in the low-tech industry because in that case I40 will take time before to be part of the manufacturing process. Future research needs to analyze also this aspect.
We hope that this contribution will motivate other research in this interesting and challenging aspect about the relationship between I40 and BM.

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