The influence of different innovation enablers on the adoption of Industry 4.0 by SMEs and large companies.

A comparative case study

Giacomo Gherardo Villa
Abstract

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This research uses a comparison among seven different case studies to study how different innovation enablers leading to Industry 4.0 have different effect on different sized companies. To do so, the seven companies taking part in the study are divided between SMEs and large companies. In order to develop the framework which is then deployed to the companies in the form of a self-assessing questionnaire along with open questions, relevant literature from both the study of innovation adoption and Industry 4.0 is used. The findings of the study, which due to respondents’ availability is limited to Italy, suggest that two main groups of enablers are very important for SMEs and three group of enablers are relevant for large companies. While both groups value the decrease in the cost of operations and the government incentives currently available in Italy as important enablers, the large companies also consider the prior organisational readiness to adopt industry 4.0 as crucial. The study also finds that another dimension which would be interesting to investigate in order to better understand the adoption of innovation by industrial manufacturing companies regards the type of production performed by the company, identifying customised production as more open and ready to adopt Industry 4.0 on a large scale.

The thesis has been developed in collaboration with Rohrbeck Heger GmbH along with a consulting project having a very similar objective.


**Popular science summary**

In the last decade, the industrial production scenario has started to adopt a new technology introduced under different names, the most notable of which is Industry 4.0. The name comes from the German industrial plan *Industrie 4.0* developed in 2011, shortly followed by similar initiatives from different countries. This new technology sparked huge discussions about whether it is the beginning of a fourth industrial revolution (from which the term Industry 4.0). Companies, legislators, industrial associations, consultants, journalists, economists were all of a sudden interested in modular technologies that have started being developed decades earlier, but that if combined, producers claim, would be able to generate a totally new way to manage the production process of any good, reducing consistently the cost of managing a more discrete production and potentially challenging the economics of scale production.

On the other side of the innovation, the adopters are currently facing the difficult decision-making process of deciding if and in which form to adopt the technology, and to which degree should it influence their own production processes. This thesis investigates how this process happens and how the different elements that are found more relevant according to the available literature come to influence it. In developing this research project, a theoretical framework has been established that enabled the combination of different elements having very scientific background in order to understand completely the reason that lead some innovation enablers to be more influential when evaluated by the potential adopters. A further hypothesis that led to the creation of the research questions is that companies with different dimension would have different decision-making processes, and the influence of the enablers would be different according to the size of the company. This completes the framework of the research, as the main focus of the thesis is formulated in order to understand which enablers influence the most the adoption of Industry 4.0 solutions by large and small companies, and which ethical consequences would this have, in their view, on the life of the people currently employed in each company.
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1. Background

1.1. Introduction to the problem

Industry 4.0 is one of the most discussed industrial-economic topics in the latest years in the most advanced economies. Many countries are heavily investing in it, either directly or through tax subsides, and while everyone involved in it has an idea about its implications, fewer actually know what its technical solutions consist in. Even fewer know how these solutions actually concur towards the development of the very ambitious objective of developing a completely new level of lean manufacturing and supply chain. Market’s first movers already deployed several different solutions while at the moment (May 2018) a big early majority can be identified in adopting at least partially these innovative solutions mostly thanks to the incentives mentioned above. The adoption of Industry 4.0 solutions also creates big ethical dilemmas regarding the future of the unskilled workforce it is aiming to substitute and the possibility that even white-collar work will, slowly but inexorably, start to suffer from this growing competition from machine and automatic systems. This leads to the question regarding whether this unavoidable industrial revolution will be a competence enhancing or a competence destroying innovation and to a wider series of ethical and economic dilemmas such as the taxation of robotic work, as suggested by Bill Gates (Delaney, 2017).

In order to better understand why the Industry 4.0 technology is such a disruptor to the industrial world, it is needed to understand at first one of its most important enablers. The Internet of Things, or IoT, is a radical new approach to the interaction between digital and physical world. It can be said that it is the networked interaction of everyday objects, which are often equipped with ubiquitous intelligence. Although it is more commonly known as an everyday “object” or “entity” with which everyone is interacting, there are various definitions of Internet of Things. This is due to its ubiquitous nature, and to the fact that its technology is one of the main enablers for most of the innovations that are prospecting to happen in the next decade. Politicians as well as practitioners increasingly acknowledge the Internet of Things as a real business opportunity and estimates currently suggest that the IoT could grow into a market worth $7.1 trillion by 2020 (Wortmann & Flüchter, 2015).

Industry 4.0 is a current trend of innovation in production facilities closely related to IoT. The term Industry 4.0 comes from the German strategic key initiative in high tech innovation “Industrie 4.0” which was set up in 2011 and was, within a few years, followed by similar initiatives by the most industrialized countries. The Industry 4.0 concept, being still in its early stages of technological development, has seen during the last few years a wide discussion about the definition of its core principles and innovation. This process, which can be summarised as a dominant design selection (Schilling, 2008) saw many stakeholders discussing and proposing different guidelines and definition being firstly based on the 2011 German plan, but then eventually evolving as enabling technology, complementary goods and the installed base grew. In 2016 a qualitative word recurrence research was performed (Hermann, et al., 2016) on most of the academic and non-academic reports and papers regarding the topic. Thanks to high-level qualitative analysis four shared main guidelines based on the different design proposals were identified. These guidelines are the result of a very intense scientific and economic investments and tend to be, rather than a winner-take-all, a combination of the relevant innovations. Namely, the guidelines are:

- Interconnection: Via the Internet of Things, interconnected objects and people are able to share information, and this forms the basis of a joint collaboration for reaching common goals. This modernization allows Industry 4.0 connected facilities to flexibly adapt to fluctuating market demand.
- Information transparency: Through linking sensors data with digitalised plant models, a virtual copy of the physical world is created. To analyse the physical world, raw sensor data must be aggregated to higher-value context information and interpreted.
- Technical assistance: In the smart factories, humans’ role tends to shift from being the operator of a machine to be a strategic decision maker and problem solver. Currently the interface through which the human operators interface with the connected factory is the smartphone, or tablet. Thanks to this, humans can control in real time the situation of facilities, and experts predict that with further advances in robotics the physical support of humans will be another aspect of technical assistance, as robots are able to conduct a range of tasks that are unpleasant, exhausting or unsafe for their human counterparts.

- Decentralised decisions: They are based on the interconnection of objects and people as well as transparency on information from inside and outside of a production facility. It allows to utilize local along with global information at the same time, for a better decision making and increased overall productivity. The components of the IoT tend to perform their tasks in the most autonomous way, and only in case of exceptions, interferences or conflicting goals tasks are delegated to a higher level. Several researches led to this conclusion, claiming that it is reached the best compromise between ordinary and extra-ordinary operations through an hybrid architecture of the system (Meissner, et al., 2017).

In this moment the main traditional players in the development of this kind of solution are also starting to create products that are not anymore a mere technology-showing-off, but rather proper adoptable solutions that might eventually substitute traditional production systems and the big players in industrial production (which are sometimes part of the same conglomerates that develop Industry 4.0 solutions) are deploying this kind of solutions at such a level that Industry 4.0 can be considered as having reached a phase of early majority adoption.

1.2. **Purpose of the study**

The main purpose of this thesis is to develop a model to assess the influence that the different innovation enablers have on the current state of Industry 4.0 solutions and strategy within a company through a self-assessment questionnaire. The development of this questionnaire, based on the current literature, will consist in the first and more theoretical part of this work. Once the model is developed, the second part of the thesis will consist in the deployment of the mentioned questionnaire and the gathering of data from different organizations in order to analyse the current state of development of the fourth industrial revolution distinguishing between small and large companies. This is a challenge due to the wide dimension of the topic, to the jeopardized adoption of the technological innovation and to its relative short time of discussion at academic level. Due to this reason, a qualitative study has been preferred over a quantitative one in order to have a wide result which considers not only the current capabilities of each subject, but also considers the opportunities that Industry 4.0 will create in a medium to long term future.

The academic motivation of this study lies in the lack of evaluation models concerning the strategy companies are adopting in regards of this new disruptive technology. In my eyes, the fact that Industry 4.0 is being developed and deployed at a very fast pace due to governments’ concerns about economic competitiveness dragged away important academic attention, focusing all the available resources on more remunerative and short-termed projects such as the development of the above-mentioned governments strategic plans.

1.3. **Definition of research question**

In order to better understand the direction of academic and empirical research of this thesis, it is meaningful to have a brief discussion about the question formulation and about how each specific term included in it has
a very specific meaning. Starting from the idea that this thesis aims at studying the difference in the use of *innovation enablers* that *different players* have, with this section it is my aim also to define what those two “buzzwords” actually mean and to focus the whole research towards a more specific direction.

During the first explorative period (under academic terms), I have been able to identify a detailed list of sectors which see a higher implementation plan of I4.0 solutions (PwC, 2016) and others which see opportunities enabled by Industry 4.0 more on a longer term. From the two list, results of two different studies performed by PwC on the topic of Industry 4.0 at a Global and at an European level, I chose to first focus on the Industrial manufacturing industry due to its position at the heart of the Italian, German, Swedish and generally European economies. In fact, official reports state that manufacturing is the core activity of 9.0% of the total number of non-financial business economy (Eurostat, 2017). While the general manufacturing production is recognized to be such a core and important economic activity, it still remains a bit too wide to have consistent results in the purpose of this thesis, and this is the reason why I chose to focus on the further subcategory of mechanical-metallurgical manufacturing. This choice is the result of a combination of personal and academic factors such as being the non-typical industrial sector in which Industry 4.0 is publicized, it has a very diverse composition in terms of dimension of the companies operating in it and is closely related to my bachelor studies. In fact, most of the available reports on the topic study the application of Industry 4.0 solutions to cutting-edge sectors, while there are less research projects regarding the adoption of such technological innovation in economically important, but technologically less innovative, industrial sector such as the mechanical-metallurgical manufacturing. The choice of this very specific industrial sector also raises a further point, which relates to the very base of the economic structure of the European Union. In fact, the number of people employed by SMEs is almost twice as much as that employed by large (>250 employees) enterprises. Making a clear distinction in my research between SMEs and large companies will also allow to evaluate how Industry 4.0 trends align or dis-align according to the dimension of the company.

This paragraph gives a clearer understanding of the term “different players” formulated in the proposed question mentioned above, tightening its border and at the same time already delignating a segmentation in it. The other keyword that emerges from these first research question considerations is “innovation enablers”. Melissa Schilling (Schilling, 2008) identifies several types of innovation and in order to better understand what these “innovation enablers” for industry 4.0 are, two couples of these types of innovation are worth to be discussed. The first couple are the product and process innovation and the second couple are the architectural and component innovation. Component innovation, also known as modular innovation, consists in the innovation of a single component but doesn’t entail a radical innovation of the system in which the module interacts as a whole. Oppositely to this stands architectural innovation, which signifies changing the overall design of a system so that the individual components, which don’t have to necessarily change, interact with each other in a different way. Product innovation are embodied in the outputs of an organization and regards the introduction in the market of a new product or service by a company and this is usually the more visible and obvious type of innovation. On the other hand, process innovations are often oriented towards increasing the effectiveness or efficiency of a production system, for example allowing the company to reduce the defect rate or increase the flexibility of the output of the production system at any given time. Combining these four definitions it is identifiable what the term “innovation enabler” is considered in this research: In fact considering the whole production innovation under Industry 4.0 logics as a process innovation, we can assimilate the single workstations innovations as product innovation. Differently from Schilling’s definition, but still using the same logic, it is thanks to the single product innovation (which in our case can be considered the innovative production techniques such as additive manufacturing, for instance) that the whole process technologically evolves and changes.

Using a similar logic in regard to component innovation and architectural innovation the single innovation at workstation is a modular innovation, which can be integrated under an old architecture, but the contribution of these innovations, especially at organizational level, allows companies to develop an architectural innovation. Moreover, Rogers (Rogers, 2003) identifies several factors which constitute the sociological
enablers for an innovation to be adopted by an organization. These factors are as important as the new technology itself because they concur with it to its acceptance as strategic requirement by the decision-making management of the different companies. Those factors, which will be discussed later in the thesis are constituted by mainly two categories: adoption factors and organization innovativeness. The first one, adoption factors, consists in a list of factors (enablers as they will be named in this thesis) that concur in creating the acceptance of an innovation need and then adoption within an organization. Nevertheless, the very same items can be used to evaluate the individual choice of adoption of an innovation and it is interesting how Rogers claims that usually innovations require an individual decision rather than organizational decisions.

The analysis and discussion of this statement will be further analyzed in the thesis as SMEs tend to have a decision-making chain smaller than those of bigger corporations (O'Regan, et al., 2005). On the other hand, the second category of innovation adoption enabler consist in a more organization-oriented set of items which evaluate individually the characteristics of the management and culture of the organization, which in this case will be the individual company. Finally, another meaning of innovation enabler comes from Johnsson(2016), who assesses innovation management in an even more organizational perspective, and among the several definitions of innovation enabler he considers, he mentions the strategy that a company has for short and long-term innovation plans. It is of great importance to mention that the paper (Johnsson, 2016) has a rather different approach to the topic of innovation, assessing it as the development rather than the adoption, and this is the reason why some of the other enablers he mentions are not related with the purpose of this thesis. A more detailed discussion about this will be done in the literature chapter. The concurrence and connection between the two types of innovation enablers (product and managerial) considered in this research’s specific context along with the innovation strategy pursued by firms creates the basis for the actual definition of Industry 4.0 as an architectural innovation:

“For a firm to initiate or adopt a component innovation may require that the firm have knowledge only about that component. However, for a firm to initiate or adopt an architectural innovation typically requires that the firm have architectural knowledge about the way components link and integrate to form the whole system. Firms must be able to understand how the attributes of components interact, and how changes in some system features might trigger the need for changes in many other design features of the overall system or the individual components.” (Schilling, 2008)

Having considered all the above-mentioned issues, the research questions of this thesis concerns the study of the different use of innovation enablers by SMEs versus big-sized companies, with the keywords defined as in the previous paragraph, using a questionnaire based comparative case study to evaluate these differences. The research question can be formulated as follows:

Q1: Which innovation enablers have the strongest influence on the decision to adopt Industry 4.0 solutions in SMEs as opposed to Large Firms?
Q2: Why are the identified enablers so important for one of these two groups of companies?

1.4. Structure of the thesis

The thesis is structured in six parts, and it has a waterfall structure, meaning that it might result difficult to understand a further part without having the knowledge gained from each of the previous chapters. The first chapter includes a general introduction to the problem, a purpose of the study and the formulation of the
question. This creates the bases to further develop and structure the literature chapter which follows. The second chapter has a first approach on the two main sources of innovation enablers in the field of Industry 4.0, being those the enablers of innovation adoption and the technical enablers of Industry 4.0 and concludes with a general overview of the two. In the following chapter the final outcome is the structured model to analyse the data, along with a final version of the self-assessment questionnaire to be used to gather the data from the companies. The formulation of this questionnaire will be discussed at a theoretical level, and a copy of it is reported in the appendix 1. The fourth chapter will report the outcomes of the field research and the fifth will discuss it in comparison to the relevant available literature in the field. Finally, the sixth and last chapter will include a brief discussion regarding the limitations of this thesis and possible further developments for the study.

Fig. 1, Structure of the thesis
2. Theory

This chapter will first introduce the different sources of innovation enablers specifically referring to Industry 4.0, thus considering both general innovation enablers having a role in the adoption of any innovation and the enablers that have a specific role in the adoption of this technology for the companies subjects of the study. This second group of enablers, discussed in section 2.3., have a more technical origins while the first group of enablers, named innovation adoption enablers and discussed in section 2.2., trace their origins back to social-sciences. Also, a general overview over the analysed literature is provided in section 2.1. An ethical dimension is also taken into consideration in chapter 2.4. To conclude, a theoretical framework is established in section 2.5. in order to be able to structure the research that will follow in the next chapters.

2.1. Literature overview

As the final aim of the theoretical part of this thesis is to develop a model able to compare the adoption and implementation state of Industry 4.0 between different sized firms in a specific field, the very first type of theoretical research performed by the author consisted in looking for already available models. Although a big number of models is available through a brief online research, most of these models result to be inconsistent for the purpose of this research. In fact, they tend to be designed for direct practical character and have been developed mostly by consulting companies either to give a digital tool to companies to self-assess their position compared to the market, and thus to potential competitors (PwC, 2016) or to give an idea to producers of Industry 4.0 solutions of their current standing in the market (CGI, 2015). These kind of research though result valid only under a strictly commercial logic, but not truly relevant for academic purposes. On the academic side, there have been some attempts by researchers to develop specific models to understand and perhaps evaluate the adoption rate of Industry 4.0, but as will be discussed in the relevant chapter, none of these is fully complete under the innovation management logic I expressed in the formulation of the research question. Moreover, all the available academic material tends to approach the issue under a rather technical approach and does not fully match the needs of this research. Thus, my theoretical model will be developed starting from a general structure shared by several authors, also in fields different from Industry 4.0 but all connected to qualitative research, such as Rohrbeck (2010) or Schumacher (2016). Both these models build the evaluation and study of a specific situation, in different fields of analysis, on the use of a self-assessment questionnaire that give to the respondents the ability to answer to statements or questions in a scale going from 1 to a number to be defined, with 1 being the lower score, and thus the least likely that a respondent agrees with it, and the other number being the highest. This area will be discussed more in detail in the chapter regarding the development of the method but is mentioned here to give a general idea about the approach that will be taken to develop the literature review. In fact, in order to deploy such a model, it is required first of all to identify the items that will then be evaluated. Those items are the innovation enablers that have been discussed in the introduction to the research question. Again, as described above in the question formulation, I chose to divide the enablers into two categories, with the first ones being composed by the sociological enablers that lead an organization to adopt a specific innovation and the second ones being the more technical list of modular innovation introduced by Industry 4.0 concurring to the architectural innovation of the fourth industrial revolution.

2.2. Innovation adoption

Innovation adoption is a wide topic discussed by several authors. Among them, Everett M. Rogers is recognized as the initiator of the modern sociological approach to the diffusion of innovations and, among other things, firstly developed the s-shaped model of innovation adoption. Starting from his own perspective,
several other researchers developed further studies in order to evaluate how, under not only a sociological but also an organizational prospective firm tend to adopt innovations. It is interesting to mention that the idea that different sized firms have a different approach to innovation adoption has already been discussed at an academic level (Comacchio & Bonesso, 2007; Kamal, et al., 2016) and the proven result has been that small firms have greater flexibility to innovate while focusing on incremental innovations, while large companies tend more to focus on radical innovations. This is due to the very own characteristics of the two different companies, with the small companies having a lower availability of resources, needed to adopt a radical innovation, as well as having the ability to handle more risk. An enabler that can lead to the measurement of this difference is given by Rogers (2003) and is named re-invention, defined as the degree to which an innovation is changed or modified by a user in the process of adoption and implementation. Especially the implementation of an innovation within an organization is closely related to the members of the organization, and especially to some specific profiles (Morden, 1989) within it. Another important point raised by previous research is that innovation adoption does not require an extensive R&D activity (Kim & Nelson, 2000) because the organizations are not required to create new knowledge, but rather to identify potential requirements, conduce an exploration phase during which select the best provider of the technology and deploy it. To conclude, another difference in the innovation adoption between individual decisions versus organizational decisions is that the first one, generally, require less time to be adopted by a majority rather than the second. The more persons involved in making an innovation decision, the slower the rate of adoption (Rogers, 2003). Clearly, one way to speed up the innovation adoption even in bigger organizations is to reduce the number of individuals involved in the decision process.

All the mentioned factors influencing innovation adoption will come useful during the final analysis of the data acquired but are still not relevant for the identification of innovation enablers. In order to do that, a definition of diffusion (and, thus, of innovation diffusion) should be given. Rogers (Rogers, 2003) defines it as the process in which an innovation is communicated through certain channels over time among the members of a social system. This definition is indeed very wide and can be used also for individual adoption of innovation. Moving to a wider organizational view it should be considered that, while the definition is still valid if considering each firm as a single ‘unit’, other dynamics interact in it from within each single organization. Thus, there would be two different levels on which the innovation adoption process happens: the general adoption factor of an innovation and the innovativeness of an organization. These two different levels create two different dimensions of analysis in this thesis, being both relevant to the understanding of different decisions pursued by different firms.

2.2.1. Adoption Factors

In this sub-paragraph the focus will be on the factors that influence an individual to either adopt or discard an innovation. Those factors are widely discussed by Rogers (Rogers, 2003), who also provides a model and a classification to understand how they concur towards the acceptance or rejection of a proposed innovation.
The five different categories (or types, as called by Rogers) of variables that concur towards the adoption of an innovation result to be of interest for this thesis because are academically recognised as having a very high correlation with an innovation adoption (up to 50%). Moreover, although they have a general approach to technology adoption and not specifically focused on the organizational issue, they can be used to understand the reasoning that stands behind a specific strategy adopted by a firm in regards to adoption of industry 4.0. In order to make the following discussion more understandable, in this paragraph each potential adopting organization will be named adopter.

I. The first cluster of adoption factors that will be discussed is the perceived attributes of adoption. It is the characteristics of innovation as perceived by each potential adopter. A brief discussion of every single element follows:

1. Compatibility: It is the degree to which an innovation is perceived by the adopter as consistent and compatible with the existing values, functions, objectives and needs.

2. Complexity: It is the degree to which the adopter perceives the difficulty to adopt and deploy the new technology

3. Observability: It is the degree to which an innovation is observable to the potential adopter. This relates to the adoption by competitors, suppliers and customers and by the interaction of opinion leaders (this element will be discussed later) in the adopting organization with it.

4. Triability: It is the degree to which Industry 4.0 can be experimented by the adopter. As in Rogers (2003), new ideas that can be tried on the instalment plan are generally adopted more rapidly than innovations that are not divisible.
5. Relative advantage: It consists in the perception by opinion leaders that Industry 4.0 is better than the current solutions employed in the production process. Although the relative advantage is a very common metrics to evaluate the potential adoption of a new technology in monetary terms, in analyses such as ROI or payback period analysis, in this study I choose not to openly mention any monetary figure in order to avoid any potential conflict with firms policies of not disclose these numbers. This enabler is considered in this research only in the short to medium term, in order to understand better the strategic choices of the subjects of study.

6. Preventive innovation: It is the concept of early adoption due to the perception that otherwise the lack of innovation will create unwanted future scenarios. It opposes to incremental innovation, which provides the desired outcome in the nearer future and then has a more quantifiable relative advantage. This element is not considered by Rogers among the perceived attributes of innovation, although being mentioned in his studies as a relative advantage. Nevertheless, in my opinion while studying the adoption of such a radical innovation as Industry 4.0 the idea of preventive innovation has a strong relevance because of the perception that adopters might have regarding the future competitiveness in the same market might direct the decision-making process towards considering this type of strategy (Rogers, 2002).

II. The second main element delineated by Rogers is relative to the kind of innovation decision. It has been proven that Industry 4.0 has had, especially in some countries, a strong push from national authorities. Three kinds of innovation decision are described, and they are:

1. Optional: are choices to adopt an innovation made on individual base, totally independently from the decisions of other members of the system.

2. Collective: are the decisions led by a general consensus towards the adoption of the innovation. The kind of influence that the general choice creates can result in an optional innovation decision, for instance to keep competitiveness in a specific market or in an authority innovation decision, such as the result of a referendum.

3. Authority: the choice is made by few individuals in the system and influence all the members of it. An example can be a new norm in regard to safety rules in industrial facilities.

This element can be quantified in point V, when the extent of individual actions performed by change agents will be evaluated. In this point, questions will be deployed in order to understand to which extent external change agents (such as government policies and market competitiveness) influence the choice of a company. This specific point is referred to the action of external agents of change, as in section 2.2.2. the action of internal change agents will also be taken into account.

III. The communication channels used by an innovation to spread are the means by which the message gets from the source, thus the producers and sponsors of the innovation, to the potential adopters of the same. This element, although designed for a sociological research on individual adoption of innovation, can easily be adapted to the current research. In fact, Roger’s definition regards more the categorization of individual communication channel such as mass media or interpersonal channel. This very same approach can be developed in two ways to be inquired to adopters of Industry 4.0 in the means of how the general public opinion and the diffusion of the technology among competitors influence the specific choice of adopting it.

IV. The nature of the social system considers the very own structure of the social system into which the adopter is placed. This element is extremely wide to assess under scientific terms, because it should consider the whole business cluster around the adopter of the technology and especially in such a customizable field as Industry 4.0 the connection between the producer of the solution and the adopter is extremely important. Again from (Rogers, 2003): “The sharing of a common objective binds the
system together”. This can give an idea of the degree of importance that the connection between the producer of I4.0 solutions and the adopter has.

V. Change agents are identified as agents who provide a communication link between a resource system with some kind of expertise and a client system, without themselves becoming involved in the process (Ottaway, 1983). Their main role within the innovation adoption logic is to connect the adopters to the promoters and producers of a new technology, facilitating the communication between the two parts and, consequently, the flow of innovation. In the previous research, change agents can be divided in three main different categories. They are:

1. Change generators: they are the creators and/or initiators of the innovation or change, and among them Ottaway creates a further division. This kind of change agent is relevant when an innovation is still in its very early phases and it needs to be known to a wide public. A specific sort of change generator agent of special interest for the purposes of this research is composed by the economic incentives, academically recognised as a key actor in deploying a specific government strategy widely in the economy (Griffith, et al., 1996). These subsides already constitute in many countries the core of the adoption factors identified by governments as being more relevant and more easily implementable by the executives (European Commission, 2017) and are heavily being implemented, along with other factors (especially in countries which started the adoption of this innovation to a large scale, such as Germany) that will be discussed in the following paragraph.

2. Change implementors: they are the change agents keeping up the diffusion rate of the change and in a general corporate structure they can be identified as the consultants performing a specific duty related to the strategy, but without changing it.

3. Change adopters: this last category of change agents is composed by the actual adopters of a change, which is in this case the adoption of Industry 4.0 solutions. Their adoption will influence competitors and other departments of the same companies towards the adoption of the same technology, if its deployment would create any specific strategic advantage.

This list of factors influencing the adoption of an innovation is only a brief schematization since its full discussion would require more than just this thesis, but it should give an idea about the importance that these mostly sociological factors have although the discussion has been focused towards Industry 4.0 and its adoption.

2.2.2. Organization innovativeness

Another important category of variables that are identified by Rogers (Rogers, 2003) as relevant to innovation adoption are composed by the peculiar characteristics that concur in creating the attitude a specific organization has towards innovativeness. This second set of innovation enablers, differently from the previous one, is already considering the innovation adopter as an organisation and is therefore more easily understandable in the logic of this thesis. Several studies agree that innovation in an organization has a strong direct link to the own organization innovativeness (Kessler, et al., 2015; Rogers, 2003) but, the very same study (Kessler, et al., 2015) agrees that a balance configuration between organization innovativeness and a cautious and perhaps slower approach to the innovation is generally having a greater innovation adoption success. Thus, connecting with the strategy that the organization pursues, it means that in order to successfully adopt an innovation this should not be merely adopted by it, but the different members of the organisation should also work along the decision-making body in order to successfully implement it. This very same topic is also analysed in detail by Rogers, who created a detailed list of independent variables having effect on the dependent variable of organizational innovativeness.
Rogers identifies three main categories of variables, using a similar approach to the one used in the identification of the adoption factors. Differently from the previously analysed list of enablers, these have a system dynamics approach to the final result, meaning that a variable can influence the organization innovativeness in both a positive or negative way. Looking at Fig. 3, those variables having a (+) sign have a positive correlation while those having a (-) sign have a negative correlation, and thus adopting the basic notion of positive and negative correlation from system dynamics (Sterman, 2000), a higher value in the (-) variables will reduce the organization innovativeness. Rogers, on the other hand, agrees that in early studies a rather low relationship has been found between the independent variables and the dependent variable.

A detailed discussion of each category and variable follows:

I. Individual leader characteristics: It is widely recognised that effective leadership is one of the most important ways of directing and steering a project, both through NPD process (McDonough & Barczk, 1997) and through the more general innovation implementation process (Sarin & McDermott, 2003). Moving to a wider company’s innovation perspective, leadership maintains its strong importance especially in the optics of opinion leaders (Turnbull & Meenaghan, 1980). Considering the management of a firm as the sample of discussion, there are opinion leaders that serve as pace-settlers for the group, determining the adoption of the innovation for the group. The attitude of these decision-making individuals towards change, thus, creates a strong precedent for the adoption of a specific innovation, and in general for the innovativeness of the organization as a whole.

II. The internal characteristics of each organizational structures influence to various degrees the innovativeness of the organization as a whole. Specifically, the six elements identified by Rogers have a strong influence on the same. They are:

1. Centralization: The degree to which the decision-making process, and thus power and control, in the organisation are concentrated in the hands of few people. This variable is considered having a negative correlation with innovativeness as the more the power is concentrated in an organization, the less innovative it tends to be. This correlation can be widely proved by, for example, the innovation strategy pursued by Google (Wentz, 2012), where innovation is delegated to each component of the organization and the leaders only delineate the strategy it should pursue.
2. Complexity: It consists in the degree to which the organization members have a higher or lower level of knowledge and expertise. This is generally expressed in terms of the formal training they have, in both practical and academic fields. It has a positive influence in the innovativeness of the organization, but on the other hand it makes it difficult for components with different training to accept the innovation proposed by others.

3. Formalization: It is the degree to which the organization members are asked by the management to follow rules and procedures. A synonym of this term can be bureaucracy, which has a general worse understanding but the very same meaning. This variable has a negative effect on the general organization innovativeness.

4. Interconnectedness: It is the extent to which the members of the organization are liked by interpersonal networks. Higher interpersonal connectedness is positively related with innovation.

5. Organizational slack: It consists in the amount of available uncommitted resources available for the organization. This refers to every type of resource, spanning from money to amount of time that members of the organization can assign to innovation projects. Rogers (Rogers, 2003) correlates this variable with the following point 6, consisting in the size of the organization. He hypothesizes that larger organizations tend to have more slack resources than smaller and this is the reason why they would be able to adopt innovations with a higher complexity in a shorter time than smaller organizations. This variable is positively correlated with the organization innovativeness.

6. Size: In Roger’s research, the size of an organisation has always been positively related with the organizational innovativeness of the same, regardless of the specific size unit of measurement. This specific item results extremely helpful for the purpose of this thesis, as being included in the formulation of the research question as key focus of research.

III. The last element of interest to evaluate the organization innovativeness is composed by the external characteristics of the organization, namely represented by the system’s openness. This represents the degree to which the members of the organization are connected or linked with other individuals who are external to the system. These connections can create information flow to the organization with the final result of making the opinion leaders more aware of the state of the art of a specific innovation outside of the firm’s boundaries and creates a positive attitude towards innovation.

2.3. Innovation enablers of Industry 4.0

Various authors tried to identify the main components of a proficient implementation of Industry 4.0 complete solutions. Among the others, Strange & Zucchella (2017), Hermann et al (2016), Shumacher et al (2016) and Roblek et al (2016) try to identify specific technical and managerial elements that concur in its creation. In order to have a first wider view of the enablers, Schumacher (Schumacher, et al., 2016) created a structure into which 62 items are divided among 9 dimensions. These dimensions are:

- Products
- Customer
- Operation
- Technology
- Strategy
- Leadership
- Governance
- Culture
- People
Some of the elements are also discussed in the previous section regarding the innovation adoption in a general perspective, while others result more peculiar to the study of deployment and implementation of a new industrial technology such as Industry 4.0. The categories also clearly divide between a more technical and a more managerial and social sciences related perspective, creating the precedent for further classifying the different modular technologies mentioned during the question formulation. Being Industry 4.0 such a wide topic also in terms of disciplines that study it, it should be clear that it shouldn’t be approached as a closed system, but rather should be considered as a part of a wider IoT revolution happening in every side of our lives (Bartodziej, 2017). Products in Industry 4.0 get the very new concept of being an active part in the development and production process thanks to several technologies gradually introduced through Industry 4.0 (Alasdair, 2016). Newly designed, smart, products incorporate various sensors having the purpose to collect data regarding very specific utilization parameters in order to reuse that very specific data for further purposes, such as a continuous product development for those companies who produce items interested by this (Porter & Heppelmann, 2015). In the fourth industrial revolution data collection exponentially gained importance, as compared to the previous product development models (Schmarzo, 2013).

Another key area that should be mentioned as a big innovation introduced by Industry 4.0 is the possibility to increase the quality of products especially thanks to simulation tools, which allow to reproduce the whole value chain and potentially reduce faults by up to 75% (Schuh, et al., 2014). Simulation also will enable a reduced process and product development stage, further reducing the time to market and, consequentially, increasing the profits and shortening investment payback time (Schuh, et al., 2014). In order to achieve this predicted reduced deployment time, another key enabler is flexibility, implemented through the usage of several process management techniques and the speeding of the increment of inter-departments collaboration (Brettel, et al., 2014). The combination of these three enablers leads then to a general increase in the efficiency of the production (Schuh, et al., 2014), which is one of the main economic drivers of the whole architectural innovation of Industry 4.0.

2.4. Ethical implications of Industry 4.0

As briefly mentioned in the introduction chapter, full scale implementation of Industry 4.0 will create new and unseen ethical dilemmas principally regarding the consequent downsizing of required workforce required for operating the same processes. This topic, although not directly related with the different enablers that drive companies towards the adoption of these solutions (not directly, but a reduction in workforce costs is often seen as an easy way to cut costs in a company (Wang & Seifert, 2017)) is extremely relevant for the social implications that this new technology will create. Other authors tried to address the same topic from a more labor-market and political science perspective and their findings correlate with the future needs of a modern welfare state (Tiraboschi & Seghezzi, 2016) and bring back the topic raised by Bill Gates (Delaney, 2017) that new sources of tax income should arise in order to maintain the social structure of the welfare state. Another issue that raises from the discussion of social implications of Industry 4.0 relates to the education of the future work class 4.0 (Ford, 2015). It is a rather widely agreed idea that the full-scale implementation of this new technology will create a disruption in workforce required skills, and most of the Industry 4.0 developing plans deployed by various government around the world take this in consideration when designing the future formation and education plan but can create an early obsolescence for those who were educated in the previous logics of production. This can indeed create a great social problem, at least as big as the above-mentioned reduction in workforce and companies will have to choose between re-educating their own workers or hiring younger, more skilled, ones. Some industrial clusters already started collaboration projects aimed at improving the skills of current employees (Faller & Feldmüller, 2015), but a real national plan is not considered in any of the various government-led plans, although several academics agree that this would be the only way to avoid the risk of a reduction of jobs in the future for those less educated (Arntz, et al., 2016).
2.5. Establishing the theoretical framework

The connections between the previously mentioned topics of discussion create the theoretical background onto which I base the research activity of this thesis. Industry 4.0 is being widely discussed lately, and companies adopting its solutions have different needs and requirements not only on a strictly technological perspective, but more comprehensively on a strategic and organizational perspective. In order to distribute the various drivers identified within different fields of innovation management studies and make the results of the research more easily understandable, a framework is created. This framework is similar in its structure to that created by Schumacher (2016) and is based on the division of the different enablers in different dimensions. A proposed value for the number of dimensions is 8, that reaches 9 summing the ethical implications questions. A list of each dimension, along with a short discussion of each and of the enablers, divided by dimension, follows:

1. Products: This dimension is relative to the importance of new possible developments of the products manufactured by each company using Industry 4.0 and aiming at creating a further step of PLM (Product Lifecycle Management) even after the sale of a product. Here specifically two enablers have been identified. They are:
   a. Quality improvement: It has been identified as a key ability of industry 4.0 to improve the general quality of the production processes and, consequentially, the quality of the products themselves. This can happen through several different improvements spanning from an improved design phase to a continuous individual control over defective items and processes allowed by the miniaturization of sensors and their integration with the system through the IoT.
   b. Smart products: Several authors, among which Michael Porter (2015), agree that in a short future information collected by already sold items will be crucial for the development of new generations or new families of products. This can lead to the shortening of development cycles and to more precise address of customers’ needs, optimizing the expenses into which enterprises incur during the product development phase.

2. Customer: This dimension relates to the improvements that Industry 4.0 creates in the customer relation and customer requirements for the firm adopting Industry 4.0. Specifically, it addresses:
   a. Individualization: Individualization has always been an expensive practice in production, and while modularization partly allowed customers and producers to enjoy its benefits, modularization isn’t by definition a full individualization according to each customer’s needs. Industry 4.0 brings new technologies to the mass-market and allows firms to have individualized and automated product development and production processes, in order to match the smallest requirement of the customers for a cost that, according to some researchers (Schuh, et al., 2014) will be as low as mass-produced items.
   b. Time to market: The advantages mentioned for the individualization are also valid for the reduction of time to market. Automation in each stage of the production process will further lower the time required to design a product, create the supply chain necessary for its production and produce it.

3. Operations: This dimension includes all the enablers that might influence the strategy of a company regarding its operations.
   a. Flexibility: It is the ability to change the products being processed in the production line minimising the time off and the costs for the company. The trend of individualization requires this kind of capability in order to maintain the production aligned with the requests of the customers
   b. Efficiency: One of the main aims of Industry 4.0 is to reduce the costs of production. In order to do it, increased efficiency is indeed a very important enabler. This element refers to both
increased efficiency in terms of lower defect rates and increased efficiency in the consumption of resources needed for the production process.

c. Re-invention rate: This enabler is relative to the cost of adoption of Industry 4.0 as an innovation for the company. Re-invention rate, as mentioned in section 2.2., is the degree to which an innovation needs to be modified in order to adapt to the requirement of its adopters. In this specific case it refers to both the readiness of a company to adopt this kind of solution, thus to adapt its own internal procedures to the new situation, and to the readiness of Industry 4.0 innovations to be deployed as out-of-the-box solutions in each specific situation.

4. Technology: This dimension is relative to the perception and level of triability of the technologies introduced by Industry 4.0. All of the enablers included in this category match the definitions given by Rogers (2003).

   a. Complexity: It refers to the complexity of Industry 4.0 as perceived by the company. A higher perceived complexity can influence negatively a decision of adoption, and subsequently create a certain degree of resistance towards that adoption.

   b. Compatibility: It refers to the level of compatibility that Industry 4.0 has with the current production processes of the company.

   c. Triability: It refers to the degree to which the company has been able to try Industry 4.0 solutions before considering their adoption.

5. Strategy: This dimension is relative to the decisions of strategic relevance related to the adoption of a disruptive innovation. In the field of Industry 4.0, specifically, it relates to the perspective strategies that can be adopted by the company also in relation of their competitors’ strategies. The main difference between the two items is relative to the distance in future of the expected results.

   a. Preventive innovation: It refers specifically to the idea of preventive innovation as discussed in section 2.2.1., considering preventive innovation as the willingness of the company to invest in an innovation that is not strictly required in one specific moment in order to then be able to exploit the results of this investment in a medium to long term future, avoiding incurring in any unwanted scenario.

   b. Relative advantage: It refers to the relative advantage in terms of cost of production, time to market, flexibility and other enablers previously discussed that Industry 4.0 will bring to the company as compared to its competitors. This advantage will come to happen in a short-term future.

6. Organizational innovativeness: This dimension is relative to what discussed in section 2.2.2. It contains all of the factors that work towards the innovativeness of a specific organization. It is the only dimension that is not designed to specifically evaluate the enablers for the adoption of Industry 4.0, but rather the general innovativeness of the organization. Obviously, this innovativeness influences the adoption of any innovation, therefore Industry 4.0 is also influenced by it. The first three enabler assess the characteristics of the organization of the company, while the latter three are focused on the study of the company as a network, and can be traced back other than to organizational and innovation management studies also to data mining techniques (Povost & Fawcett, 2013).

   a. Organization complexity: It refers to the perceived complexity of the organization, thus to how specialized are the roles that each employee has within the organization and how their roles can be interchanged.

   b. Centralization: It refers to the level of centralization that the organization of the company has, and how the decisions are taken by a few individual or rather driven by more people within it.

   c. Formalization: It refers to how many rules are set within the organization according to each specific situation or if, oppositely, to solve those situations members of the organization are freer to approach a situation according to their individual knowledge.

   d. Diffusion network: This element relates to the way an idea is able to flow within an organization. Rogers(2003) agrees that very often the spread of new ideas happens through
interpersonal networks within an organization, but other factors might reduce the level of flow of ideas. This element, disunited from the item that measures interpersonal networks, aims at evaluating the level of ideas that spread around the organization rather than the number of connections themselves.

e. Change agents: They provide a communication link between a resource system with some kind of expertise and the client system, thus the company in this case. One main role of the change agent is to facilitate the flow of innovations from a change agency to an audience of clients. Change agents can be then considered superconnectors of the system, if seen considering a data mining logic (Povost & Fawcett, 2013).

f. Interconnectedness: This element considers the degree of complexity of the interconnectedness of different members of the company.

7. Competitors: This dimension refers to the way that the company is able to see how its competitors are adopting or are not adopting certain types of Industry 4.0 solutions.

a. Critical mass: It refers to the perception that the company has of the adoption rate of Industry 4.0 by its competitors, whether or not this reaches a point that makes the innovation mandatory in order to remain competitive in the market.

b. Observability: It matches the idea of observability given by Rogers (2003), and in this specific case it refers more in general to the level to which the company is able to observe the adoption of Industry 4.0 in the industrial cluster surrounding it.

8. Leadership: This dimension is relative to the internal leadership of the company and of external leadership within the economic structure.

a. Incentives: This element is relative to the presence of economic incentives provided by a higher entity to the company. This higher entity results very often to be the state, and the economic incentives are very often expressed in the form of tax deduction in the current plans of Industry 4.0 in the most advanced countries.

b. Opinion leader: This element relates to the presence or not of an opinion leader who is able to influence the decisions taken by the organization. This opinion leader can be both internal or external and can influence either directly either indirectly the decisions regarding Industry 4.0 taken by the firm.

c. Attitude towards change: This element relates to the attitude towards change of the actual leadership of the company.

9. Ethical implications: As discussed in section 2.4., Industry 4.0 takes along several severe ethical implications especially regarding the future development of the workforce structure. The two elements used for evaluating how companies see this happening are the following:

a. Reduction in Workforce: Industry 4.0 technologies will enable the automatization of operations that were considerate a prerogative of human beings so far. This can either create a destructive disruption, only removing human workers from their current duties, or create a constructive disruption, allowing human workers to take more specialised and creative jobs (Ford, 2015).

b. Request for more skilled workers: As already introduced in the preceding enabler, workers will probably need to develop new skills in order to keep competitiveness against automated work.

The list of 23 enablers and 2 ethical consequences, divided among 9 dimensions, create the theoretical framework on which the operative part of this thesis will be developed. A detailed discussion about how they will be studied will follow in the next chapter 3.
3. **Method**

The way this research has been conceived and developed has been based from the earliest moments on a self-assessment questionnaire giving to the respondent the responsibility to self-evaluate his or her current state of adoption of Industry 4.0 solutions. To further process the collected data, the items (which are represented by the innovation enablers) are then grouped in different categories with the aim to be able to create a comparison between SMEs and big corporations in terms of impact of the innovation enablers. The model which is used to collect and process the data is discussed in detail in section 3.2. and the procedures applied during the formulation of the self-assessment questionnaires are discussed in section 3.1. They are discussed earlier in order to give consistency to the following research design definition.

The design of the research method has been developed after earlier considerations developed throughout the whole research process. Having started this project with the idea of evaluating how current technology (thus defining enablers as only technological elements) enables the adoption of Industry 4.0 by different players in the market, the main focus slowly but decisively shifted towards the study of the way different adoption factors, from this point on identified as innovation enablers, work in different sized companies in the metal-mechanical manufacturing sector. Therefore, as it became clearer that the topic was originally too wide and that perhaps it would have been more specific to identify a precise area of discussion in which to develop the original idea, two key factors were identified: *innovation enablers* and *different players*, as defined by the dimension of the company.

Another development that is interesting to mention is how the research method of this thesis, which is close to both qualitative and quantitative research, is addressed. The research method design, and specifically the way the self-assessment questionnaire is designed, would suggest that this study is conducted in the form of a quantitative study, but on the other hand the deep interest of understanding each single case and the possibility for the respondents to share their thoughts about each single enabler create the possibility to assess each situation individually, and only afterwards to assess the comparison between different sized companies. Therefore, although quantitative data analysis can be performed, and will be mentioned in some points, it will not be the main research method also due to the dimension of the sample. On the other hand, the topic of qualitative research methods is very wide and spans way over the boundaries of this thesis. Nevertheless, it is useful for method validation purposes to investigate whether the proposed method complies with the general guidelines identified by the main researchers, such as Bryman & Bell (2003) or Denzin & Lincoln (2005).

### 3.1. **Self-assessment questionnaire**

Scientific usage of self-assessment questionnaires (or self-administered questionnaire as sometimes referred to) is usually connected with qualitative research, specifically in the case of having to collect large amount of data coming from a wide variety of respondents in a short time. Obviously, each questionnaire should be designed specifically around the knowledge field of each respondent. It is very similar in purposes to the other widely used qualitative research method of structured interview (Bryman & Bell, 2003), but differently from this it is not required for the interviewer to be physically present at the moment of compiling it. This widens the horizons of administrability of the questionnaire to basically the whole world. This advantage, on the other hand, opens the doors for related topics such as the methods to effectively formulate the questionnaire since the absence of an interviewer would, in case of negative impression from the respondent, lead to a possible failure.

General disadvantages of self-assessment questionnaires, according to (Bryman & Bell, 2003), include:

- Need to formulate the questions in the clearest way, since in the moment of filling it up nobody will assist the respondent.
- Impossibility to probe respondents in case the provided answer is not fully satisfying, applies only in case of open questions.
- Impossibility to ask questions that are not of high interest for the respondents, or otherwise face the risk of low response rate due to lack of interest.
- Difficulty in asking many open questions, which very often result harder to respondents. Respondents very often dislike when they are required to write a lot, and therefore the inclusion of open questions should be carefully calibrated.
- Difficulty for questionnaires to avoid correlation of answers if the respondent is able to see in advance further questions. This is especially valid in case of paper-based questionnaires but is still relevant also for internet-based ones, as often several questions are listed on the same page.
- It is difficult to deploy long questionnaires, as respondents tend to be affected by the so called ‘respondent fatigue’ (Hess, et al., 2012). This phenomenon occurs when participants become tired of the survey and as a result the quality of the data they provide begins to deteriorate, if not leaving the remaining part unanswered at all. This creates the basis for the next disadvantage of self-assessment questionnaires. An interesting factor is that there is no clear “maximum number of questions” suggested in a self-assessment questionnaire, but rather the optimal dimension has to be established experimentally according to the type of research to be conducted. In this specific case, I will base the dimension calibration on previously conducted similar result. Specifically, (Schumacher, et al., 2016) gives precise figures about the response rate of its own research, and with 23 responses out of 123 distributed questionnaires is decisively unsatisfying. This indicates that a list of 62 items to be asked, as this research has, is perhaps too long to generate consistent results. This thesis will then have a lower number of enablers (correspondent to the individual item in Schumacher et al (2016)).
- Risk of missing data. It is likely if not expectable that some respondents will avoid answering some question, either for personal reasons or for the above mentioned ‘respondent fatigue’ phenomenon.
- Low response rate: this limitation can have different origins, but the risk that it creates is that different biases by different category of respondents result in a falsified result.

All these considerations come to play in the formulation phase of the questionnaire, and, where it is possible to reduce the risk of falling into any of these, the relative solutions are taken. An example is given by the consideration done regarding the number of enablers to be evaluated.

3.2. Research process and data analysis models

Before starting with the discussion of the details of the model, a general outline of it is given in order to make the reader able to follow each step of the development of the model. Specifically, 6 main parts are identified as important to highlight how it will be addressed:

- Enablers grouping in the eight dimensions
- Self-assessment questions, open and closed
- Completeness of the research
- Data analysis (qualitative)
- Case discussion
- Identification of similar and different patterns

As already mentioned, the innovation enablers are grouped in the different dimensions identified in the theory chapter. These dimensions are then used to draw a profile for each company and give the possibility to create a detailed image of the two different groups (SMEs and large companies) identified in the research question, providing the terrain for further discussion related to the different technology adoption patterns. The different models of data analysis available in the speciality of research performed using self-assessment
questionnaires very often reach a similar output. We can see that a similar pattern is followed by Rohrbeck (2010) and by Schumacher (2016) other than, partially, by Bartodziej (2017). All of the mentioned studies give to the respondent a scale to answer to each question with a self-evaluation, but two clearly different approaches are taken. On the one hand, Schumacher (2016) and Bartodziej (2017) use a 1 to 5 scale, while oppositely to this Rohrbeck (2010) uses a 1-4 scale, also taking into consideration the research previously performed by Kahn (2006). These two approaches open the field for the discussion of whether the scale should give an even or an uneven number of choices. In this research the second approach will be used, because it avoids the impasse of the average score on which respondents might fall in case of a doubt regarding a specific answer. Doing so the results will give a more truthful representation of the actual status of things within each organization. The way the possible answers are represented in the questionnaire will consist in a scale representing the description of each innovation enabler and asking to which degree the respondent sees that influencing the adoption of Industry 4.0 solution. Then multiple-choice ballots will give the possibility to choose one answer among the four levels. A rough sketch of it follows:

How important is the possibility to increase the quality of the products for your company’s decision to adopt Industry 4.0 solutions?

1  2  3  4

Very low  ○  ○  ○  ○  Very high

Fig. 4, A screenshot of the enablers self-assessment questionnaire

The questions are divided in different pages, with all of the questions of the same dimension represented at the same time on the same page. This is a measure to reduce (but not to delete) the possibility of correlation bias in the answers. It is also interesting to consider that this decision is the result of a trade-off between the risk of answer correlation and reducing respondent fatigue. Once a dimension is completed, the interviewee will proceed to the next category with a special button. A final consideration concerns the design of the questionnaire. Bryman (2003) identifies as the most effective design a vertical design, as opposed to horizontal design, due to the lower possibility of misunderstanding by the respondents. Nevertheless, in this research the horizontal format has been chosen because the answer given by the interviewees will always extend in the same series of shades, spanning from a very low agreement to a very high agreement.

Following each enabler’s question, a compulsory open question is also posed, in order to understand the specific reasons of the most extreme choices. This allows to formulate the current research as qualitative, and thus reduce the number of respondents (no statistical relevance required) and evaluate each single case in order to understand the general picture, thus taking into consideration each individual motivation that led to a specific choice.

If you answered 1 or 4, would you like to provide any specific reasons for your answer?

Testo risposta breve ...........................................................................................................

Fig. 5, A screenshot of the compulsory question that follows each enabler self-assessment question 
Finally, in order to avoid the bias of total closeness of this specific type of qualitative research, a multiple-choice question regarding the completeness of the questionnaire is formulated in this way:

“Do you think that the innovation enablers leading to Industry 4.0 adoption mentioned in this research are a complete representation of the enablers you have had the possibility to interact with?”

The answers that the respondent will be able to give will be the same 4 levels, but as final question, following the same structure used before, it will be asked whether there are more elements that he or she sees as relevant innovation enabler.

After the data collection the next step consists in data elaboration. The model mentioned above, due to its usage of similar methods of quantitative research also delineate a detailed process for this step, and in this case, specifically, I based the construction of the structure on the method developed by Schumacher (2016). This model has several similarities with Rohrbeck (2010), mostly due to the data processing and final representation of the data. In order to collect all the enablers of each category under a single value, and be able to graphically represent it, the following standard average-calculation formula was used, applying for each dimension of each company.

$$M_D = \frac{\sum_{i=1}^{n} A_{DE_i}}{n}$$

With the various indicators having the following meaning:

$$A = \text{Degree of agreement (to the enabler; from 1 to 4)}$$
$$D=\text{Dimension}$$
$$E=\text{Enabler}$$
$$n=\text{Number of Enablers in the Dimension}$$

A final consideration to be made regards those enablers that Rogers (2003) identifies as having a negative correlation on the organizational innovativeness as a whole. Those two elements are namely centralization and formalization, and both are identified as a separate enabler in the current framework. Only for those two enablers, it will be applied the following formula:

$$M_E = 4 - M'_E$$

With the various indicators having the following meaning:

$$M=\text{Maturity}$$
$$E=\text{Enabler}$$
$$M'=\text{result as provided by the respondent}$$

This allows to consider the enabler as having a negative correlation, as described in the basics of system dynamics (Sterman, 2000).

Once each respondent’s closed answers are represented on a graph, it is possible to have a general idea about each situation, and therefore integrate it with the open answers provided by the respondent in order to understand each specific situation. Each single result is introduced in detail and only then a general discussion is brought up, comparing the actual differences in the adoption of Industry 4.0 by different sized firms and trying to give an answer to the research question. Finally, a conclusion chapter finalizes the findings and describes possible further developments of the research.
In order to make the discussion more intuitive in terms of graphical representation, the method of radar representation, also used by Rohrbeck (2010) and by Schumacher (2016) is used. In fact, both models use a Radar representation to render in a single picture the results of the analysis of each single organization, and this very same structure can also be then further used to compare the results of one firm or cluster of firms to other firms or cluster of firms of interest. An example of Radar representation by Schumacher (2016) follows:

![Radar representation](image)

**Fig. 6, Radar representation of the final results, divided by category** (Schumacher, et al., 2016)

Note: This is a different model and is only shown here to introduce the graphic representation that will be used. In this model there are 5 maturity levels, while in the current research only 4 will be used, moreover the dimensions of the study are different than those considered in this thesis.

### 3.3. Subjects of research and method validation

This research, also considering the importance of the topic in nowadays industrial strategic plans, has been designed to allow respondents to maintain total anonymity regarding their company. This is especially relevant for medium and large companies, which tend to be more secretive about their strategies. This ‘secrecy oriented’ design allows the research to be able to reach a wider public. The respondents of the questionnaire, each representing the company they work for, have different roles within each society. The main problem regarding this rather uneven selection of roles is that each different company has a different approach towards the adoption of Industry 4.0, and therefore in different organizations different roles have the same level of knowledge about this new technology. The precise role of the respondent is reported in Table 2. In total, seven companies are assessed in this study.

In order to validate the questionnaire, four validation tests were conducted with the help of different academics from different universities. Their contribution is reported in Table 1. After all these validation
rounds, the questionnaire re-emerged deeply modified and with a more appropriate language formulation and more appropriate structure. In this thesis, only the final version of the questionnaire is reported in the appendix.

Table 1, background of the respondents to the pilot questionnaire

The way respondents have been selected is variegated: a first number of respondents has been contacted according to personal connections of the author and of its colleagues at Rohrbeck Heger GmbH, then the major European companies in the metal-mechanical manufacturing sector have been contacted through their general email or central telephone number and finally a last set of companies has been contacted during the Hannover Messe, which took place between the 23rd and the 28th of April 2018 and that the author visited intensively.

Due to the respondents’ secrecy agreement, only a few basic information about each company are provided such as the nation where the company is based or the dimension of the company in term of workers employed. While the first identification question doesn’t relate deeply with the purpose of this research, but rather is only used for identification purposes, the second one is extremely important because it is identified by Rogers (2003) as key variable having a direct effect on the organizational innovativeness. Moreover, the size of the company is also included as key variable to then develop the discussion of the research question. Interestingly enough, although the thesis has been designed to compare different companies from different countries, only Italian companies actually replied and were willing to take part in the study.

Table 2, Questionnaire respondents
4. Results

In this chapter the result of each single questionnaire is discussed in order to reach an understanding of each individual situation. Interestingly, although the research was designed to compare different local realities, the respondents who agreed to take part in the study are all from the industrial cluster of Northern Italy. This creates the basis for a more precise type of case study, as the local variables that act on each company are shared among all the respondents of the survey.

The results are presented in the form of a short case study, thus in a very qualitative approach, but the main findings of each questionnaire are also submitted in the form of quantitative results (that is, as radar representations). The data will then be discussed using a mixed method (Somekh & Lewin, 2005) that implies at first a general analysis of the numerical results and then a qualitative analysis of the specific situation using the open answers provided by the respondents and the available literature to evaluate each situation. Each respondent gave different responses to the qualitative questions and while some were more open to share the smallest detail about their company/their experience, others resulted more reserved and didn’t share many information other than the answering to the questionnaire. This can be caused by either a general concern about the privacy of the company or by a limited amount of time spent in answering the questionnaire.

Another point to make clear before starting the introduction of the results regards the structure of the research questionnaire. As previously mentioned, it is researching which innovation enablers are having the highest influence on Industry 4.0 adoption, and why these enablers are so important for the respondent. Due to the high number of enablers being considered, those are divided into different dimensions as described in section 2.5., creating a framework of 8 functional dimensions plus one extra dimension investigating the impact that Industry 4.0 will have on the workforce of the companies. In the individual cases introduction, only the 8 functional dimensions are discussed, while a section listing the aggregate findings regarding the ethical dimension of the study follows the individual cases.

4.1. Case 1

The first respondent is a company with more than 500 employees. According to the classification that will then eventually create the prerequisite for further discussion, it is classified as large company. The respondent in the company has a role of R&D engineer within the field of production technologies. The numeric self-assessment was overall rather balanced, as shown in the following picture:
As noticeable from Fig. 7, the company tends to have a rather uniform pattern. This reveals that although they have awareness of the current implications of Industry 4.0, they are not yet fully considering its strong future potential, especially in terms of consideration of Industry 4.0 as a relative advantage towards its competitors (thus the short term strategic advantage that it will create). This is explained by the answers given in the Strategy dimension by the respondent. It is also of interest to notice how although the general outline of each dimension is rather positive, reaching an average level of 3, indicating a rather strong commitment towards innovation adoption, while on the other hand the company has a rather low self-assessment score on the organizational innovativeness, having almost one point less, on average, than all the other dimensions. The respondent didn’t leave any further comment on the answers (which were always ranged between 2 and 3) and agreed that the survey has a rather wide and comprehensive set of enablers to evaluate the innovation adoption by a company.

4.2. Case 2

The second company to answer the self-assessment survey is a small enterprise (<50 employees). The respondent in the company is the sole engineer working in it, and thus has a very wide view of every production process and decision-making process happening in it. Being the company so small, the levels selected for each enabler are much lower than the previous case 1, due to reasons that will be investigated in chapter 5.
In this case, it immediately jumps to the viewer’s eyes the very low score that the company has in the products, customer and strategy dimensions, all of which don’t score more than 2 with the strategy dimension being the lowest at 1.5. Among the three, the latter one is the lowest and the respondent gives as explanation the reason that Industry 4.0 is not considered by the company as a preventive innovation, thus enabling the company to overcome future competitive challenges, because some of the technologies were already mostly available due to the government tax incentives to adopt this new technology, which in Italy have been available since early 2017. In the open answers, the respondent also explained how this incentive has also played a major role in the adoption strategy, and how according to his opinion it was the only real reason that this technology has started to get used by the company. Interestingly, moving to the product and customer answers, he also explained how the products produced by his company have a very high standardization and therefore it is of no interest for them to increase the quality of the production, to increase the individualization of the products, to reduce the time to market or to introduce any sort of smart product. On the other hand, he also agrees that it is interesting for them the possibility to increase the flexibility and the efficiency of the production, which especially in the first case sounds a bit opposite to the previous statement of no real interest in the increase of quality. Individual strategic choices definitely play a role in this contradiction, especially considering their B2B business model (as all the other companies involved in this study). Different strategies of the companies involved in the study will be further discussed in chapter 5, as one of the main differentiators within each dimension group.

The company also considers Industry 4.0 as rather difficult to understand, try and implement in their current production line. Although no specific reason has been given, this can relate with some of the answers given in the Organizational Innovativeness dimension, where he explains that due to the very small size of the company (22 employees) there is a high interconnectness among them, but on the other hand he also points out that nobody else other than him holds any upper or lower university degree (not even the owners, who still manage the company). The fact that the owners manage the company is, according to his responses, the main reason of a high centralization of the decision-making process. Moreover, he identifies the leadership (thus the
owners) of his company as reluctant adopters of innovation, not oriented towards change until it becomes necessary. A final consideration he made about the innovation strategy at this company regards the low rate of adoption of Industry 4.0 by its competitors: as their specific business area is still slow at adopting it, nobody among them can be considered as an early adopter (on large scales), and therefore they are also not considering Industry 4.0 as a relative advantage.

4.3. Case 3

The third company which replied to the survey is a medium-sized enterprise (50-500 employees). The respondent works there as supply chain optimization engineer, currently optimizing the operations of the three production plants of the group.

![Fig. 9, The results of the questionnaire as aggregated by dimension for respondent 3](image)

This company has some dimensions of specific strength and some others of perceived weakness in terms of innovation adoption. The two strongest dimensions result to be Customer, with a score of 3, and Operations, having a score of more approximately 3,6. The respondent highlights the big importance that increased flexibility has for the company due to their business area, which consists in the production of highly individualized items, with non-repetitive production. Moreover, he also expressed how in his opinion the adoption of Industry 4.0 solutions will help the company in avoiding competition due to the increased efficiency of the new processes. On the other hand, he also states that up to date Industry 4.0 solutions have been used in the company only for controlling purposes and not for wider production operations, without having the possibility to even try those technologies. This can relate also with the strategic dimension, where the company scores rather low in terms of perception of Industry 4.0 as a preventive innovation or relative advantage by the management of the company. Being the strategy highly influenced by the innovativeness of the company and by its leadership, it is noticeable that organizational innovativeness is the lowest dimension.
in the radar representation having a score of 2. Again, as in case 2, the respondent agrees that in his company every decision is taken by the “boss”, who is the CEO and owner of the company, whom is also rather resilient towards the adoption of innovation in the respondent’s opinion. This traditional approach also influences the diffusion of innovations within the employees, which as enabler (thus in Fig. 9 aggregated within the dimension ‘Organizational Innovativeness’) scores only 1 in the self-assessment questionnaire. Regarding the competitors’ adoption of Industry 4.0, the respondent agrees that although its adoption is reaching a critical mass, its adoption is scarcely noticeable within the industrial cluster. A final consideration is made regarding the availability and influence of Industry 4.0 government incentives, which still results as a very strong enabler of the innovation adoption.

4.4. Case 4

The fourth company answering the survey is a small sized company, with less than 50 employees. The respondent is a junior project manager in the company, and from a preliminary assessment of whether this role gives him a wide-enough view over the company to answer the survey, he suggested that in such a small company his role was covering pretty much all of the departments and thus he would be able to answer to the questionnaire.

Fig. 10, The results of the questionnaire as aggregated by dimension for respondent 4

This company, compared to the previous three cases has a rather unequal distribution of its results. This can relate with the business area of the company, which consists in the production of individualised items according to specific customers’ requirements. Considering this, it is understandable why they consider very important the possibility to increase the quality of the products, to individualise the products for a lower cost and to increase in general the efficiency of the operations, which in case of individualised production using current industrial methodologies come at a higher cost, mostly due to the high fixed costs. The same strategic market orientation also explains how the respondent didn’t consider the possibility to reduce time to market as an important enabler for the company.
Nevertheless, the respondent agrees that the company considers Industry 4.0 as having strategic importance for the company in both preventive innovation and relative advantage terms, thus implicitly saying that the technology has a short-to-medium and long-term impact on the firm’s results. This strategic awareness of the importance of Industry 4.0 doesn’t match the competitors’ current situation, being this dimension the one with the lowest score of only 1.5. This emphasizes the low perceived adoption rate of Industry 4.0 in the company’s cluster of competitors. Another weak point regards the technology itself, being considered not compatible with the current production system and with the company that has never been able to try it before adopting it.

Moreover, the respondent suggested that government incentives are at the moment perhaps the main reason its company was investing in the adoption of Industry 4.0, and although the leadership of the company is not very oriented towards change investments in that direction are currently being made.

4.5. Case 5

The fifth company answering to the questionnaire is a mid-sized company having between 50 and 500 employees. The respondent is the supply chain manager of the company. It should be noted that the respondent was new in the company, having worked there for less than a year when answering the questionnaire and thus might not be fully aware of the more sociological dynamics within the firm.

![Fig. 11, The results of the questionnaire as aggregated by dimension for respondent 5](image)

This company, as seen previously with other SMEs, gives a lower score to the strategy dimension, thus not considering Industry 4.0 important in terms of future competitiveness. On the other hand, the company results quite interested in the product implications of Industry 4.0, considering both the increase of the quality
of products and the possibility to implement smart products as important. The respondent also considers important for his company all the process-related enablers, such as the reduction of time to market, the increase of the efficiency of the operations.

The technological implications regarding Industry 4.0 for this respondent were rather diverse. In fact, if on the one side he states that his company has never been able to try these kinds of solutions, on the other he also agrees that his company doesn’t consider Industry 4.0 as difficult to understand or use and they consider the technology as compatible with their current production systems. Even considering this possible positive match in terms of technology deployment cost, in their strategic view they don’t consider Industry 4.0 as a preventive innovation, and they slightly consider it as a relative advantage. It is interesting to see how important is in their view of the adoption of Industry 4.0 the possibility to create positive results in the short term, but less important the advantages and implications that this technology will bring in the long term. This can perhaps be justified by the negative opinion that the respondent has regarding the orientation towards change of the leadership of his company, but on the other hand is not justified by the rather high observability that Industry 4.0 has in their industrial cluster and by the opinion that the respondent has regarding the reach of a critical mass of adoption of this technology by their competitors. Again, like in some other previous cases the different perception that the respondent has as opposed to the people deciding the strategical plan of the company might be the reason for this mismatch, also considering the very high centralization of the organization. Interestingly, in this case government subsidies and tax deduction are not focal in the decision to adopt Industry 4.0 solutions.

4.6. Case 6

This company is a large company (>500 employees) based in Italy but having production operations in several continents. The respondent is the purchasing manager of the company, whom is responsible for the procurement of every needed good in each production site. This gives him a rather wide view over the overall adoption rate and strategy of Industry 4.0, as each new purchasing order has to pass through his office and he held that position over the last decade.

**Fig. 12, The results of the questionnaire as aggregated by dimension for respondent 6**
The company from a first view of the overall result is more deeply involved in the adoption of Industry 4.0, which is perceived as having a strong importance for most of the enablers covered by the self-assessment questionnaire. A general overview can indicate that although most of the dimensions are valued with high scores by the respondent, the organizational innovativeness is, on average, much lower than the others. This pattern happens also in many of the other cases, but in this case is more easily observable as it is the only dimension scoring lower than 3.

The respondent considers extremely valuable the possibility to increase the individualization of single products as that would enable an acceleration of the decision time, mostly due to the currently very long development cycle time of each product. He explains that due to the extremely low standardization of their products, a higher flexibility in the production line and along with it higher automation in non-standardized operations is of extremely high interest for the company. The same reason explains other answers given by the respondent, such as the importance given to a lower time to market, or the compatibility of Industry 4.0 with their current production systems, as he explains, due to the current non-standardization and thus easily flexible but expansive, current production strategy. This high flexibility would enable the company to easily adopt the new technologies and insert them in their current procedures eventually automating some operations that are performed by highly trained and specialised workers.

Another point that the respondent highlights in different parts of the questionnaire is relative to the high influence that government incentives played from the first moment on the decision-making process of the company. This is so important that the incentives themselves came to become considered a relative advantage in the short run against competitors, most of which are non-Italian and are not subject to the same incentives. Although the company and its management is aware of the future importance of the technology (the respondent gave a score of 3 to the perception of Industry 4.0 as a preventive innovation), their adoption strategy was driven by short-term advantages. On the other hand, this strategy might also be related to the high adoption of Industry 4.0 solutions in their whole industrial cluster, where the respondent agreed that it is very highly observable, and by the reaching of a critical adoption mass by their competitors.

A final consideration is done regarding the perceived weakness of the respondent’s company in terms of innovation adoption. The organizational innovativeness of the company is seen as rather low at the moment mostly due to the very high centralization of the decision-making process and by its rather formal culture. The respondent, though, sees Industry 4.0 as a way not only to improve the efficiency in operations of the company, but also to improve its innovativeness, as he says that when Industry 4.0 will be totally implemented every worker will be connected and informed of each change or decision, and this will allow the spreading of ideas to flow freer.

4.7. Case 7

The seventh company which took part in this study is a mid-sized company. The respondent of the questionnaire is the production manager in the company’s sole plant.
Fig. 13, The results of the questionnaire as aggregated by dimension for respondent 7

The results of this questionnaire show how this company’s perception of the enablers is very shifted towards the customer, operations and products dimensions, but scores low in the competitors and organizational innovativeness, as many of the previous companies also do.

Interestingly, this company is not very interested in increasing the quality of its products but is rather interested in the possibility to develop smart products. In doing so, they see individualization along with a reduced time to market as the key enabler to offer smart products. Regarding operations, the respondent sees as rather important the possibility to increase efficiency and flexibility in their production operations, and considers their current operations as being rather ready to adopt this type of solution without the need for a big re-invention of it to be deployed. As with case 6, this is due to the currently low standardized production caused by their business model. The respondent explains that the company has been trying to develop a first batch of Industry 4.0 technologies internally, with an early manufacturing execution system (MES) developed by the company itself but not reaching high levels of efficiency. In his opinion, this creates a good starting point also in terms of readiness of the employees to deal with further external solutions to be then adopted by the company. On the other hand, the company has not been widely able to try external Industry 4.0 solutions before their adoption.

Strategically, the company sees Industry 4.0 as a relative advantage in the short run, but less important in terms of preventive innovation, thus implicitly agreeing that in their industrial cluster the adoption of Industry 4.0 is not going to be a big advantage in the long-term future. Interestingly, although the overall score tends to be rather balanced towards a high influence of the innovation enablers on the strategy of the company, the respondent considers the leadership of this company as not oriented towards change. This can be related to the
extremely low diffusion of innovations within the company, the low connectedness among the members of the company and to the very low connections the company has with change agents. Another key factor that tends to be rather common for all the respondents of the questionnaire regards the very high centralization of the company, which according to the respondent for this company is 4, thus very high. Moreover, its competitors tend not to adopt Industry 4.0 solutions, and not to make the few adoptions they make observable. Finally, as in many cases earlier mentioned, the respondent agrees that at the current state most of the adoption of Industry 4.0 has been driven by government subsides, making it more explicit stating “At the moment this is the only true reason of adoption by our company”.

4.8. Ethical considerations of the respondents

This dimension has not been included in the previous discussion about the adoption enablers of Industry 4.0 for the reason that it is not (or at least should not) be a key factor leading a company to the adoption of Industry 4.0, but rather aims at evaluating the personal opinions of each respondent in terms of future development of the job market. Along with the several questions regarding innovation adoption, two further questions about the ethical impact of Industry 4.0 on the workforce of each company were asked, as mentioned in section 2.4. Specifically, the two questions assess:

- The impact of Industry 4.0 on the number of required workforce to perform the same production
- The new standard requirements in terms of personal skills that Industry 4.0 will create for the workforce of each company

Each respondent gave a different opinion regarding these two answers, but regarding the first question, they all agreed that the introduction of new, smart machinery will in the long-term lead to reduced size of the workforce. The answers, although agreeing on the point, indicate different degrees, and this might be traced back to the dimension of the firm having smaller companies more difficulties to practically reduce the actual number of employees due the high complexity (Rogers, 2003) of their functions. Some explanations provided by the respondents also point out that Industry 4.0 will lead to a general automation of several functions that nowadays cannot be performed by machines. On this point, they strongly agree with Ford (2015).

Regarding the new required skills, the general opinion is not as unified as in the previous ethical issue. In fact, there is not a shared vision of the future skills required from the employees. Some respondents see this wave of automation including smart solutions that will digitalise the knowledge in specific fields, thus allowing the employees to just be able to interface with the system in order to keep up the production. Oppositely to this, some other respondents see the introduction of new technology as the trigger for requiring new skills in every function interacting with Industry 4.0. SMEs and large companies do not provide any relevant difference in their considerations, and their answers tend to be equally distributed between the two.
5. **Discussion**

In this chapter the difference between the answers of SMEs and Large Firms will be discussed more in detail, finding common patterns and differences between the two. In order to make the understanding of the discussion easier for the reader, the research questions are hereby recalled:

Q1: Which innovation enablers have the strongest influence on the decision to adopt Industry 4.0 solutions in SMEs as opposed to Large Firms?

Q2: Why are the identified enablers so important for one of these two groups of companies?

In order to be able to answer to Q1 and Q2 a general comparison between the quantifiable results of the two groups has to be provided. This comparison is being done using once again the radar representation, and does not aim at being any numerical tool, but rather a graphical tool just to evaluate the points of agreement and disagreement between them. A reminder about how the research is structured needs to be done in order to enable the reader to fully understand the results of the empirical research. The several enablers are aggregated into the different dimensions as described in section 2.5. and this structure is also used to then further structure the discussion. The differences and similarities are divided as according to the dimension; thus it may happen that while a dimension has very similar results between the two groups, some enablers included in it have very different results. Finally, in order to aggregate the results of the different companies a simple average function has been used between the respondents of each group.

![Radar diagram showing the results of the questionnaire as aggregated by dimension and group size.](image)

*Fig. 14, The results of the questionnaire as aggregated by dimension and group size*

As noticeable from Fig. 14, on average SMEs tend to be less driven towards innovation adoption from the enablers included in this study. Nevertheless, there are few dimensions where the two groups get very similar
results, and there are some other dimensions where the opposite is true. This chapter is structured to analyse the similarities and differences of the perception of innovation enablers at a dimension level, and finally the ethical implications of the adoption of Industry 4.0.

5.1. Common considerations between SMEs and large companies

The dimensions where SMEs and Large Firms tend to give a rather similar level of importance to the different enablers are Operations, Customer, Products and Technology. Enablers closely related with savings in operations tend to be recognised as having a big influence for both SMEs and large companies. This area spans over the boundaries of the Operations dimension and covers also other enablers such as the increase of quality, the reduction of the time to market, the possibility to individualise products at a lower cost, the increase in flexibility and efficiency. All of the mentioned enablers constitute points of agreement between the two groups, and at the same time result to score very high on the overall scale, considering their total average. In fact, out of the five top enablers in terms of importance given by the respondent, four are included in this list. This can suggest that the key drivers for adoption of Industry 4.0 shared between both groups are those that can be expected when introducing a new production technology: a general reduction of costs in every operation, being every enabler mentioned before related to this factor in different ways. For instance, the reduction of time to market implies a lower strategic preparation of the deployment of a new product, reducing the costs of complementary product development processes such as market studies, while reducing its time horizon. Some respondents even mention the accelerated time of decision as very important for them. Another example comes from the possibility to increase production line’s flexibility, which by definition in the current industrial model includes setup costs that can be very high (Sianesi, 2011), bringing these costs down and at the same time allowing this flexible system to change production line faster than their predecessors. Further, another reason that justifies the importance of the increase automated flexibility in production is the exclusion of human influence in non-standardised production cycles.

Both groups of companies are extremely interested in anything related to cost-saving, thus creating a certain uniformity between them, but another new division arises especially in the considerations about production line flexibility, contained in the Operations dimension, and product individualisation, included in the Product Dimension. In fact, regardless of the dimension of the companies, the business model of some of them is oriented towards a very large production of standardised items, while other business models tend more towards “tailor made” production of extremely specific items, without any type of repetitive production. The difference between standardized and customized production is at the very heart of Industry 4.0 revolution, as one of the big promises related to the adoption of this technology is relative to the standardization of non-standardised operations (Schuh, et al., 2014). According to this definition, the boundaries between the two production philosophies should consistently decrease thanks to Industry 4.0, but considering an adopter’s perspective, Industry 4.0 results more interesting if the advantages it brings are bigger, and thus those companies currently having a customised production result more enthusiastic towards its adoption.

In the Product dimension, both SMEs and large companies gave importance to the possibility to increase the quality of products, but different answers were given regarding the possibility to implement smart products: once again the individual business model of each company created more difference than the dimension of the company itself, thus giving averages that result close to each other for the dimension. In the Technology dimension, companies of different dimension also gave similar importance to the different enablers, even if the gap between the two groups widens as if compared to the other dimensions from Fig. 14. A possible explanation even if not clearly stated by the respondents, for this difference stands simply in the promotional efforts that producers of Industry 4.0 solutions are making to reach out customers, starting from the biggest and moving to the smallest. This also matches the extent to which companies have been able to try Industry 4.0 solutions and how the company reputes Industry 4.0 as difficult to use, being both enablers related to the
marketing efforts reaching out to the company. No explicit mention of those marketing efforts, though, has been made by any respondent.

Finally, a dimension that scores rather low in both groups of companies, but having similar levels, is the organizational innovativeness. Within it, being the dimension including the highest number of enablers established in this thesis, there are different ones some of which tend to be considered in the same way between the two groups and some others which don’t. The more common characteristic between the two groups is the centralization of the organization. In fact, only one respondent (from one of the large companies) wrote that her company is not very centralised, while every other respondent gave the highest score, even giving precise explanations about the persons who make the decisions in the company. For instance, it is common practice within SMEs that the owners make all the decisions, while even the managers are merely delegated functions to execute. This behaviour is nothing new to the academic world (O'Regan, et al., 2005) and it is even proved that successful SMEs directly managed by their owner tend to be performance leaders in their niche. Obviously, this study refers to the overall decision-making process, and not only to the innovation adoption decision making process. Interestingly, the findings of this thesis suggest that ownership and direct management by the owners creates a rather negative bias for innovation adoption, while other studies (Mosey, et al., 2002) suggest that the same management style create very positive results in terms of innovation development. A final note in this discussion about ownership and innovation adoption regards the other large company that took part in this study: although considering its dimension, it is still a family owned business, with the top management positions occupied by members of the family. Complexity of the company is another element that sees every participant agree on a rather high level, thus meaning that in each organization the members have very specialized knowledge and functions, with low interchangeability among each other. Two elements that sees a difference between SMEs and large firms in terms of organizational innovativeness are the fluidity of the diffusion of innovations and the interconnectedness between the members of the company. It is not a surprise that these two elements have similar developments, as the diffusion of innovations within an organization is very often connected to the degree of connectedness of its members (Rogers, 2003). Interconnectedness among the members of the organization is then a final element which tends to change from company to company, without any relation to the size of the company or to any other element evaluated in this study.

An interesting consideration have to be done regarding the influence of government incentives enabler. In fact, although being included in the Leadership dimension, it sees a high level of agreement between the two groups. Every respondent except that of case 1 agrees that at the moment this is the highest motivation for any investment in Industry 4.0 technology. As mentioned in different parts of the previous discussion, many respondents made this very explicit stating that this is “at the moment the only true reason” or that “investments in this type of technology are made for big fiscal savings in the short run”.

5.2. Differences between SMEs and large companies

From Fig. 14 it is noticeable how the Leadership, Competitors and Strategy dimensions have the biggest difference in terms of results between SMEs and large companies. In the Strategy dimension, the Large Firms have a rather similar opinion especially in terms of considering Industry 4.0 as a preventive innovation, thus seeing it as a must-do in the long run but have a slightly different opinion regarding the short-term advantages: in fact, while one company does see it as a relative advantage, the other considers it less important. The company considering it as a short-term advantage, interestingly, explains how a good part of this advantage is given by the heavy government incentives available at the moment in Italy. The different opinion, considering also its motivation, might be caused also by the different role of the respondents in the two companies, in fact in case 1 the respondent has a more technical role, thus evaluating the adoption of the technology, while in case 6 the respondent is the purchasing manager of the company, a role that implicitly considers cost saving as crucial for any successful operation. On the other hand, SMEs tend to have a rather low but non-uniform
opinion regarding the strategic impact of Industry 4.0. Interestingly, the shared opinion is that Industry 4.0 is more a relative advantage rather than a preventive innovation. This matches the opinion of the respondent of case 6, also considering that several SMEs indicated government subsides as the current key enabler for the adoption of Industry 4.0.

Regarding the influence of competitors’ adoption of Industry 4.0 solutions, again it is more visible for large companies rather than SMEs both in terms of observability of the adoption of the technology and in terms of the perceived critical mass of adoption among direct competitors and industrial partners. Again, in case 6 the respondent highlights how the high observability of the adoption is related to the government incentives, of which in his opinion all their major competitors are doing wide usage. Without any substantial difference, both SMEs and large firms agree that the innovation adoption is more observable in each individual industrial cluster rather than having reached a critical mass of adoption in the same cluster.

Finally, regarding the Leadership dimension the highest difference between SMEs and large companies happens to be in the perceived orientation towards change of the leadership of the company. SMEs tend to be rather more conservative in terms of change, while large firms’ leadership is more oriented towards this type of radical change. This result matches those of previous research (McAdam, et al., 2000), matching SMEs change processes very oriented towards continuous improvement, while less oriented towards a wider and more deep innovation culture. The second enabler of this dimension, the degree of influence that opinion leaders can have on the strategic decisions of the company, shows a rather high importance in large firms with both ranking it with a score of 3, while for SMEs there seems to be no standard answer, but their influence tends to be more randomised, with some respondents considering rather high while others consider it less relevant. The last enabler, the influence of government incentives on the decision to adopt Industry 4.0, results to be the point of highest agreement between all of the respondents of the questionnaire although in a dimension that sees high disagreement between the two groups. This is the reason it has already been discussed in section 5.1.

5.3. The reasons behind the most important enablers

Each of the two groups, other than diverging for the levels of the dimensions, also had different enablers playing the most important roles in the adoption of Industry 4.0 by the companies. In this section, the enablers that resulted more important for each group are introduced and discussed not only in terms of the results of the questionnaire, but also trying to understand why these enablers are so important to that specific group. In doing so, the aim of the section is to fully answer to RQ2.

5.3.1. SMEs

Among SMEs, the highest ranked enabler results to be the government incentives. This is not a surprise, as several respondents highlighted the big importance of this enabler in the current adoption strategies not only of their companies but of their industrial cluster as a whole. Government incentives allow even small business with liquidity problem to make use of it, as in Italy they come in the form of a 250% tax depreciation on “new capital goods, tangible and intangible assets (software and IT systems) functional to the technological and digital transformation of production processes” (Ministero dello sviluppo economico, 2018). This specific government policy doesn’t just push companies to adopt Industry 4.0 but being the tax depreciation working on a 5-year period, it forces them also to develop a medium-term sales strategy to cover the actual cost of the machine, with profits that on the balance sheet will be less accountable to taxes thanks to the increased depreciation. This specific policy, on the other hand, pushes companies, and especially SMEs due to their smaller dimension to seek higher profits in the short run. This can lead the discussion towards the second
enabler more important for SMEs, increased production efficiency. A leaner and more efficient production is a key component to reduce costs (Sianesi, 2011), consequentially increasing the profits. Another of the enablers ranked among the more influent, increased production flexibility, also relates to this explanation but only if taking into consideration the specific production strategy of the specific company, as divided between standard or customized production like described in section 5.1. Finally, another enabler that results to be very important for SMEs is the possibility to individualise products at a lower cost. This enabler is also relatable to the increased flexibility in the production operations, because it is the direct result of less expansive development and production cycles. All in all, every enabler considered more important by SMEs relates to the increase of the final profit of the company, through different financial or operational means.

5.3.2. Large companies

The innovation enablers that influence the largest companies are quite similar to those having effect on SMEs, but there are some differences. The first and more obvious difference is that while for SMEs the most important enabler has on average a relative difference with the general average (around 1,5 points), for large companies this difference is way smaller (0,5 points). This is explainable due to the average highest score given to the different enablers by large companies. Like for SMEs, the highest scoring enablers are government incentives and all those enablers connected to a lower-cost, customized production. Two enablers that are not present in SMEs are the compatibility of Industry 4.0 with the current production systems, which scores 3,5 as compared to the 2,2 of SMEs, and how fluid innovations can spread throughout the organization, with SMEs having a score of 1,4 while large companies have a score of 3,5. Although considering the main reason behind the adoption of Industry 4.0 by large companies is mostly similar to that of SMEs, thus relative to a short-term increase of the revenue, it’s noticeable that the two enablers that are only present in large companies are more related to the ability of the companies to adopt and adapt the new technology to their current operations. A comprehensive set of reasons to adopt Industry 4.0 for large companies is, thus, that not only the companies seek an increase in their short to medium term profits, but also consider those technologies as compatible with their current production system and with their corporate innovation culture.

5.4. Ethical implications

The ethical implications of the adoption of Industry 4.0 for the employees of the companies that took part in this study result to be rather similar if assessed in terms of the dimension of the company, but if compared to the type of production that the companies carry out have a very different outcome. In fact, as for other factors such as the reduction of the time to market or the increase in flexibility (discussed in section 5.1.) companies having a very standardised production seem less likely to consider a reduction in workforce following the adoption of Industry 4.0. A possible explanation is that these companies already reach a very high automation level in most of their function, and they are already closed to the physical limit of workforce reduction. On the other hand, all of the companies having a less standardized production also see Industry 4.0 as more threatening in terms of workforce reduction. As Ford (2015) concludes, Industry 4.0 will probably threaten some jobs with more automation, but at the same time create more opportunity of employment in roles where humans cannot be substituted by machines such as in jobs related to interpersonal relationships, creativity, inventive.

The respondents seem less agreeing on the fact that the introduction of Industry 4.0 will also create the need for new skills in the workforce. These different opinions can come from biases related to the roles of the respondents along with the different types of business covered by the firms. Again, there is no clear distinction among the answers given by people employed in large firms and SMEs, but it seems that two very different
opinions arise. On the one hand, some respondents believe that this different Industrial approach will not create many requirements for new skills as everything will be automated and thus human influence will be even lower, while on the other hand some respondents believe that the new options introduced by Industry 4.0 will need to be matched with new skills such as CAM design ability or different maintenance management. This seems to be very related to the personal biases of the respondents.
6. Conclusion

In this chapter, the main findings and considerations regarding the thesis are introduced. The findings reflect the issues already discussed in chapter 5 and introduced in chapter 4 and reflect the situation in the Northern Italian industrial cluster. Finally, sections 6.2. and 6.3. contain the perceived limits of the study and the proposed solutions to be adopted in a future study to face these limits.

6.1. Findings

The findings of this study are related to both research questions. The initial aim of the study was to evaluate how different sized companies are influenced by the enablers leading to Industry 4.0, and during the writing of the thesis a second question regarding the understanding of the core reason behind different choices by the different groups was introduced. Concerning the first research question, the findings denote both similarities and differences among the two groups. In fact, while the SMEs only value as strong enablers several operations-related enablers and the government incentives, large companies tend to consider the technology as attractive in terms of innovation also due to their prior preparation in terms of organization and production technologies. Nevertheless, SMEs tend always to score lower than large companies in the self-assessment questionnaire, not having a single dimension in which they overtake the large companies and having several dimensions where they score substantially lower than the others. This reflects a general feeling among SMEs of distrust in the adoption of the new technology and in general to believe that the disruptions introduced by Industry 4.0 are more or less possible to cover with an efficient organization and that Industry 4.0 will not create a real revolution within their respective industrial cluster. Overall, large companies result ready to adopt the new technology under many dimension, medium companies are aware of the potential of Industry 4.0 while, at least concerning the result of this study, small companies look less ready to both adopt and accept it as a true revolution.

As already mentioned, the enablers that have the highest influence on the decision-making process of companies are the production operations and government subsidies. This is true for both groups of companies, and perfectly matches the ideal of Industry 4.0 itself: it should automatize operations where current technologies still require a strong support from humans. Most of these operations nowadays are related to the production of customised items, and due to this reason, a second division among the subjects of the study arose during the elaboration phase. This division consists in customized production as opposed to standardized production but since this hasn't been considered in the research planning phase, the companies that took part in the study are a mix of the two. This reason, along with the other reasons discussed in advance, delineate a clear group of companies whom are more likely to see these enablers as having a higher influence and another group which is resilient towards its adoption. Using a matrix representation, with the size of the company on one axis and the type of production on the other, two clusters can perhaps be identified as reported in Fig. 15.
Fig. 15, Matrix representation of the hypothesized groups and identified groups

A possible explanation for this behaviour might be the seeking of short term returns by the companies, rather than long-term ones because companies having a bigger organization and producing customized items can see the possibility to start saving costs in the shortest time. This hypothesis is also proven by the result of the self-assessment questionnaire, where respondents agreed to see Industry 4.0 more as a relative advantage rather than a preventive innovation. This, means that they see the advantages that Industry 4.0 creates rather on the short to medium term rather than on the long term. This finds a match in Rogers (2003), whom hypothesizes that short term advantages tend to have a greater influence on innovation adoption rather than long term advantage. Having considered all the reasons that induce companies to adopt the technology, it is reasonable to conclude saying that, at least in the Italian scenario, the influence of government incentives plays a key role as innovation enabler along with the increase in efficiency and saving in production costs. These enablers, though, didn’t result as important as the others for reasons spanning from the lack of adoption in the industrial cluster leading to a low environment pressure to adopt it, to the low knowledge about it of the possible adopters.

Some of the enablers originally identified, thus, resulted more important for influencing the adoption strategy of a firm rather than other, as was expectable. This perfectly matches the first research question, in which the “which” formulation suggested that one of the purposes of the thesis was to identify those enablers, among the formulated ones, having higher influence in the decision-making process.

6.2. Limits of the study

After having concluded the thesis, two main limits arise to the eyes of the reader. The first one consists in the origin of the pool of companies addressed by the study. As mention before, they all come from the industrial cluster located in the northern part of Italy, as opposed to the initial aim to compare different national realities. This limit, on the other hand, helps in making the research more focused, and thus more meaningful due to the lower variation in the external variables influencing the companies. This especially applies to the macroeconomic situation outside of the company and, perhaps even more importantly, to the type and rules of
the government incentives that are available to the company. Nevertheless, this geographical restriction of the participants makes this study valid only for a very limited area.

Another limit of this research consists in the different roles that the respondent has in the different companies. The fact that from their role they see Industry 4.0 from different perspective might create some personal biases relative to it as for instance someone working in the deployment of such solutions might be more enthusiastic about it while someone whose work is at risk of being substituted by a machine might sound more critic towards this innovation.

6.3. Further developments

A possible further development of the current study might consist in following up the study in the same companies but submit it to different people having different roles within the companies. In doing so, the study might result more comprehensive and reflect a more shared reality as perceived by the whole organization of the companies, and not only by single individuals. Obviously, in order to achieve the greatest scientific result, people having similar roles should be identified within the different companies and once the pivotal roles are identified, people holding the same role from the different companies should be contacted. In order to better understand the real motivations that induce companies to adopt Industry 4.0 solutions it might also be helpful to further develop the methodology, deploying a semi-structured interview once the respondents answer the self-assessment questionnaire (so to avoid answer biases due to the interviewer). This might also create the case to introduce new research questions along with those already inquired. Considering the current result of the research, I would also consider widen the research questions to the study of the influence of the specific government policy and to which degree would the absence of it slow down or eventually stop any investment in Industry 4.0 technologies. This also connect to the next consideration of further development.

In fact, it might be interesting to widen the geographical horizons of the study to a biggest sample, perhaps from other European countries as it was in the original aim of this thesis. This can create a wider understanding of the topic also considering the different government policies in the different countries of the study and reconnects with the proposed further research questions also assessing how the investments are policy-driven in the different countries. Nevertheless, in order to make such a study consistent under academic terms, the pool of subjects of the study should be widened, so that individual outliers shall not influence the final result, and if the new qualitative methodology would have to be implemented, thus placing side by side the self-assessment questionnaire with a semi structured interview, a big amount of resources would be required.
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**Appendix**

<table>
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<tr>
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<th>Dimension</th>
<th>Enabler</th>
<th>Question:</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>General info</td>
<td></td>
<td>Which country is your company based in?</td>
</tr>
<tr>
<td>2</td>
<td>General Info</td>
<td></td>
<td>How big is your company?</td>
</tr>
<tr>
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<td>Products</td>
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<td>How important is the possibility to increase the quality of the products for your company's decision to adopt Industry 4.0 solutions?</td>
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<td>How important is the possibility to implement smart products for your company's decision to adopt Industry 4.0 solutions?</td>
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<td>Customer</td>
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<td>How important is the possibility to reduce the time to market for your company's decision to adopt Industry 4.0 solutions?</td>
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<td>Operations</td>
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<td>How important is the possibility to increase production line flexibility for your company's decision to adopt Industry 4.0 solutions?</td>
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<td>How important is the prospected increase in the efficiency of operations for your company's decision to adopt Industry 4.0 solutions?</td>
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<td>Operations</td>
<td>Re-invention rate</td>
<td>How important is the re-invention of Industry 4.0 solutions required to match your current needs?</td>
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<td>Complexity</td>
<td>How does your company rate Industry 4.0 difficult to understand and use?</td>
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<td>Compatibility</td>
<td>How does your company rate Industry 4.0 compatible with its current production systems?</td>
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<td>Triability</td>
<td>To which extent has your company been able to try the use Industry 4.0 solutions before adoption?</td>
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<td>Strategy</td>
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<td>Is Industry 4.0 considered as a preventive innovation by your company?</td>
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<td>During your company's strategic planning has Industry 4.0 been considered as a relative advantage?</td>
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<td>How complex is the organization of your company in terms of individual ability to perform specific tasks?</td>
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<td>How formal is your company?</td>
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<td>How fluid is the diffusion of innovations within your company?</td>
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<td>To which degree are change agents in contact with your company?</td>
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<td>How interconnected are the members of your organization between each other?</td>
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<td>How would you agree with the fact that Industry 4.0 has reached a critical mass of adoption in your cluster of competitors?</td>
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<td>Incentives</td>
<td>How much government financial incentives influenced your current Industry 4.0 strategy?</td>
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*Appendix 2, List of descriptions as provided in the self-assessment questionnaire*