



Dissertation

International Business Master

Industry 4.0 – Is Portugal prepared for the future?

Rui Miguel do Couto Carvalho

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Abstract

Portugal, although never being a country that was in the front lines in the adoption and exploitation of any of the previous three Industrial Revolutions, would seem to now have a new chance in taking the lead with the fourth Industrial Revolution, the Industry 4.0.

Industry 4.0 isn't a concept with a very clear and agreed upon definition, but there are certain hallmarks that leads researchers to believe they are dealing with this phenomena. For example, technologies like Cyber-Physical Systems (CPS), the Internet of Things (IoT) and Artificial Intelligence (AI) are heavily referred when speaking of the "Smart Factories". The culmination of these technological components integrated with a production line, will permit an organization to achieve higher results, this through the optimization of processes, as well as, making the products available to the consumers faster and with more customization options.

The phenomena of the Industry 4.0 is one that is very appealing in terms of future promises that it makes, not only to the specific organization but to the host country as well. As such, a certain level of preparedness is desired form the companies within the country, in order for the adoption process be as seamless as possible. This notion lead to the creation of the "Preparedness Index", which was generated with the data collected by an online survey created for this dissertation, with the responses of 149 Portuguese companies from various business backgrounds. With this index we could analyze the validity of four hypotheses, all pondering the level of preparedness of the host country in general (H1), as well as, the level of preparedness of certain key characteristics of the specific companies (H2, H3 and H4). All of the hypotheses here confirmed, this because the "Preparedness Index" itself was proven statistically viable. With these hypotheses proven we could conclude that Portugal is in fact, a country that is ready for the new innovations that the Industry 4.0 wants to bring.

Key Words: *Industry 4.0, Smart Factories, Industrial Revolutions, Internet of Things, Cyber-Physical Systems.*

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List of Abbreviations

R&D	Research and Development
IT	Information Technologies
CPS	Cyber-Physical Systems
IoT	Internet of Things
AI	Artificial Intelligence
RFID	Radio-frequency Identification
SME's	Small and Medium Enterprises
SPSS	Statistical Package for the Social Sciences

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1. Introduction

Throughout the centuries mankind has developed new and improved ways to develop goods and services allowing the industries the capability of producing more efficiently, with better quality and in bigger numbers. In the last few centuries there have been three great industrial revolutions that reshaped the whole world, and now we find ourselves in the middle of a new industrial revolution. This fourth industrial revolution has been entitled as Industry 4.0.

The main objective of this dissertation is to attain the level preparedness that the Portuguese organizations have towards embarking in the Industry 4.0's processes and ways of approaching business. To this point, we will first be taking a deep look to the various effects of the Industry 4.0, and try to observe what will be the changes, not only to the manufacturing industry, but also taking a look at the effects that this revolution will have on the world.

The term "Industry 4.0" was first introduced in 2011 by the German government, and it is in Germany that this new revolution began to take form. Since Germany is a country that is well renowned for their engineering capabilities (Kagermann et al., 2013) and the fact that the manufacturing industry comprises 25% of the country's GDP and employees millions of individuals (Brettel et al., 2014) it only seems natural that they would be on the forefront in trying to improve and innovate in order to maintain their position as one of the leading countries specialized in manufacturing. It has been estimated that by 2025 the benefits of the implementation of the Industry 4.0 will raise 78 billion euros to the German GDP (Bauer & Horváth, 2015) once again, noting how important this transition is.

What the industry 4.0 is trying to achieve is the improvement of the manufacturing process by utilizing atomization and data collecting (Hermann, Pentek & Otto, 2016). The effects of which are brought on by the implementation sensors, microcomputers and transceivers that allow the whole factory to not only have its physical embodiment, as well as a cyber-physical structure. The amount of data collected will be so vast, due to the capabilities of the various sensors implemented on each of the machines that the term utilized for these datasets is referred to as "Big Data". These elaborate datasets will require a lot of computing power so

that they be thoroughly analyzed as to gain the largest amount of improvements as possible. This problem can be solved by the use of “Cloud Computing”, which is a tool that allows companies to utilize the computing power of multiple processors over the internet (Mell & Grance, 2011). The data after being analyzed becomes what is known as “Smart Data” (Klinck, 2014), and it will allow the optimization of the performance of the company, as well as, create larger flexibility in product customization, decrease labor costs, lower waste creation and optimize downtime for the machines (Radziwon et al., 2014). These are the biggest differences when comparing an Industry 4.0 factory, also known as a “Smart Factory”, with a factory previous to these technological improvements.

This dissertation is divided into six sections. The first section is where we approach the subject of the Industry 4.0, having a quick rundown of its origins and characteristics, as well as, the main objectives of the dissertation. The second section is where its further develop the analysis of the Industry 4.0. To accomplish this objective we also take into analysis some other concepts that give further context to this forth Industrial Revolution, like the Kondratieff wave theory, the concept of innovation and the history behind the previous Industrial Revolutions. In the third section we present the “Preparedness Index” and the reasoning behind its creation, as well as, the hypotheses that said index will be testing. The fourth section is where we discuss the selection of the country that is to be examined, the way we utilized to examine said country, tests for the validity of the results obtained and a characterization of the sample based on the responses. The data of the aforementioned selected sample will be further analyzed in the fifth section in order to either confirm or deny the hypotheses. Section six is the final segment of this dissertation and is comprised by the final analysis of the results of the hypotheses tests, a breakdown of what those results actually mean in the context of the Industry 4.0, contributions to the literature, limitations and recommendations for further research.

2. Theoretical Analysis

2.1 Innovation

The innovation process is one that creates and improves upon technology, creating new processes, products and services. In this dissertation we will be taking a focus on innovation from the point of view of organizations, but also analyzing the effects of this phenomena both in the perspective of the business world, as well as, the general population. It is important to mention that sometimes, even the innovation that is created whilst attempting to create successful earnings for an organization can have influences that will reshape the whole world, with the Industrial Revolutions being an example of this phenomena. In the business world, innovation is associated with growth, both economical and in terms of position on the market. For this purpose, organizations need to always be trying to innovate and better themselves as well as their products and services (Schumpeter, J. A. 2008). As such, organizations are investing a large quantity of their time and resources into their research and development (R&D) departments.

Innovation as a concept has several definitions, emphasizing different author's perspectives. For many, innovation stands from a point of wanting to improve upon a product, service or process, even though the possible outcome might not always be positive (Dosi, G. 1988). This desire to improve can have many motivations, like for example, trying to take advantage of a market need or even making the desire to make a process more efficient (Maryville, 1992). Innovation is often associated with a sense of creating something new. Smith, K. (2005) states that there must be a sense of "*newness*" for there to be actual innovation. For an organization this doesn't always prove itself to be the norm, since some authors consider that innovation can be achieved by changing processes, establish new connection within the

production line or even dismantle certain steps that prove to be unnecessary, all with the goal of bettering the operation (Lundvall, 1988). These types of innovations will help the company to differentiate itself from the other companies in the market (Cooper, 1994) possibly making that company's market share higher than without innovation. As such, innovation can be classified as a way to add value to the company. It is only by innovating that organizations can make sure that their customer base is well satisfied, since this process will make the quality superior, more durable and even bring the prices down.

There are three different forms that innovation can have: products, services and processes (Mortensen & Bloch, 2005).

- **Product innovation** can manifest as an improvement in machinery for the industrial sector, or as a consumer product, such as a new type of television. In the point of view of the organization providing the new product, the attraction of the product innovation is that the novelty alone can suffice to get customers to purchase the product. Ansoff (1957) classified "*new product development*" as one of the keystone strategies to improve a business, emphasizing once again its importance within an organization.
- **Service innovation**, just like product innovation, is highly important, but it is often overlooked by the consumers, since it doesn't necessarily take a physical form it will seem less attractive (Edvardsson & Olsson, 1996). A case of this type of innovation can be the higher speeds of internet that the service providers are implementing. Even so, when a service is created where once no market was, like Facebook, YouTube or even Google, it still manages to impress the consumers, sometimes even more than a physical product.
- **Process innovation** is probably of the three types of innovations here mentioned the one that affects society the most. A pertinent example of this case is the manufacturing processes brought forth by Henry Ford in the early 1900's with the Model T. Thanks to the moving assembly line, Ford was able to create affordable vehicles with less manufacturing effort, bringing forth the changing of the manufacturing industry (Milgrom & Roberts, 1995). This example shows that you don't need to necessarily innovate the product, you can achieve the same or even better results by focusing on the process of creation.

Failure in innovation sometimes occurs, and its causes can arise from sources outside of the organization as well as from within. David O'Sullivan (2002) identified the five reasons for internal failure of innovation: poor goal definition, poor alignment of actions to goals, poor participation in teams, poor monitoring of results, poor communication and access to information. Most, if not all, of the reasons for the lack of success have something to do with poor management of the workforce and other resources (Drucker, 1998). Therefore an organization that is incapable of managing their resources won't be able to achieve success when it comes to innovation. In his 1988 paper "*The nature of the innovative process*", Dosi, G. identifies three possible market failures that can occur when pursuing the innovation process.

- The first arises from the appropriability of the knowledge, meaning that if the innovation is easily replicated by the competitors than the advantage of coming up with the idea won't have a long-lasting effect.
- The second will come from the amount of investment utilized in the R&D department. As with all innovations, their future is uncertain, and more times than not, they will not reach the final stages of development.
- The third, and final failure inhibitor is associated with the price given to the product/service. When the new invention reaches the market, there are two possible ways for the company to act in regards to the pricing. Either the price given to it will be far superior to what most people are willing to pay to cover for development cost, or they will opt for a low penetration pricing, to build up market share. In terms of the product life-cycle theory (Vernon, R., & Wells, L. T. 1966) the first stage, market introduction, is where the organization will find themselves. In this stage, they will only be selling to a very limited number of buyers, despite the price. Moreover, they aren't guaranteed to ever achieve the growth and maturity stages, in which the organization sees a profit for their investment. One of the reasons for the high expenditures at the beginning of a product/service life is the fact that there aren't yet economies of scale to benefit from (Smith, A. 1776).

These are all risks that the organization need to have in mind before they even start to consider the innovation process. Therefore, the innovation process isn't easily available to every organization. Previously innovation was thought to only be achieved by large organizations, since there is a need for a large amount of cash flows to invest in R&D, to account for poor initial sales, and even for the possibility of failure and, most small organizations couldn't afford these expenses. But in recent years, ever since the rise of internet companies, there have been a large amount of innovations arising from smaller firms and startups. Mostly composed by young individuals, the benefits of the smaller firms lie in the behavioral aspects (Vossen, R. W. 1998), such as improvisation, efficiency in communicating, larger flexibility and the fact that they are both workers and their own employers also benefits their commitment. As such, the size of the organization doesn't dictate if the company is more likely to innovate or not, but it does influence which route the innovation will be made, since larger organizations will have more available cash flows they can afford to incur in some initial and R&D losses, and smaller organization, given there more liberal approach to management, can be capable of innovating in new and unusual way.

2.2 Types of Innovation

As stated previously there are some different types of innovations depending on the degree of novelty associated with them. Initially there were thought to be two types of innovation: Incremental and Radical (Abernathy & Utterback, 1978).

- **Incremental innovation** is described as introducing minor changes to an already existing product, service or process, attempting to achieve a new potential. This can be achieved by changing some components, with the objective of making it cheaper or more reliable, or by simplifying the inner workings of the product. This type of innovation can achieve considerable economic gains over time. It's also important to reference that this type of innovation will occur with to different degree, depending on the industry itself.

- **Radical innovation** happens when an organization makes a new product, service or process, with the objective of replacing an existing one for something that is considered as superior. This type of innovation often times effects greatly the market and, by consequence the other organizations within that market. Its effects are so vast that it can create new markets, change the existent ones and even render some other products/services useless. Since it makes such ripples in the market, this type of innovation is often considered as harmful for already existing organizations and can be a good way for a new organization to enter the market place. But the effects of this type of innovation will have their own massive effect within the source of the invention itself. These changes will affect both organization's strategy as well as their structure and, as such, will have to be well managed in order to maintain the results (Cooper, J. R. 1998).

In later years there were publications that challenged the existence of only these two types of innovation. In 1985, Abernathy, W. J., and Clark, K. B. created a model that would let them categorize the competitive significance of an innovation into four categories. It was called the transience map, and the categories were niche, architectural, regular and revolutionary. The reason for these extra innovation classifications is described as: “...*the successful pursuit of different kinds of innovation will require different kinds of organizational and managerial skills.*” (Abernathy & Clark, 1985, p. 20). What this is referring to, is that there are so many different types of innovative processes as they are problems to be solved, as such, this goes being the simple, is it incremental or radical innovation and steps into an area in which the manager has to have originality to achieve the better solution for their organization.

In the same line of thought, Henderson, R. M., & Clark, K. B. (1990), state that: “... *the traditional categorization of innovation as either incremental or radical is incomplete and potentially misleading and does not account for the sometimes disastrous effects on industry incumbents of seemingly minor improvements in technological products*” (Henderson & Clark, 1990, p. 9).

In this dissertation, we won't take a deeper look to other types of innovation, mainly focusing on the radical innovation. The reason for this is that our final goal is to analyse the possible effects of the Industry 4.0, which is considered to be the next great Industrial Revolution. The Industrial Revolutions are almost indisputably considered as the most extreme cases of radical innovations, given their characteristics.

Previously in this dissertation there was a brief analysis of which organization size would be more likely to innovate, either big or small organizations. Reaching the conclusion that the size wouldn't necessarily matter, and that both large and small organizations would innovate, but their approach to innovation would differ depending on the size.

There are some authors that theorize that radical innovation is less likely to occur from within large enterprises. The reason for this notion is that the process of radical innovation requires a lot of changes to the company and, as we previously discussed whilst analyzing innovation, those changes would affect the already existing processes (Rosenbloom & Christensen, 1994). The changes would also affect the organization's culture, and possibly would have to rearrange the existing workforce to better suit the innovation's demands (Tornatzky & Fleischer, 1990). As such, the company wouldn't necessarily benefit, at least in the short term, from these massive changes, especially since the beginning costs could be fatal if the endeavor happened to fail. Therefore, it would be more likely for these large organizations to continue their processes while participating in incremental innovations. As such, revolutionary innovation would be more likely coming from a small organization or even from an individual entrepreneur.

Time as shown that this is an occurrence, smaller enterprises innovate beyond their larger rivals and eventually they themselves become the market leaders. Ironically enough, after that, the same company loses its need to radically innovate, choosing a more conservative approach, which will eventually lead to its downfall, being outdated by a newer organization (Chandy & Tellis, 2000).

But this is a difficult area to make statements and take conclusions with absolute certainty. There are many gray areas in which you can draw conclusions. For example, nowadays there are a very high number of small startups that are getting immediately acquired by big corporations based on the promise of their work (Imaginatik & Masschalenge, 2016). This is

a way that big companies can use to innovate, while maintaining their other operations untouched.

Another concept that makes it hard for the small companies to develop their own ideas without the aid of bigger corporation has to do with the state of the intellectual property ownership. Large enterprises normally have a large number of ideas for products, services and processes already copyrighted (Helpman, 1992). This makes it difficult for companies with less resources to create innovate while not entering another company's intellectual property.

So we can ponder on whether or not innovation is more likely to come from a small startup, with a culture that allows for creative thinking and employees with high levels of motivation, or from a large corporation, with a lot of resources and previous knowledge of the inner workings of the innovation process. It appears that every case must be analyzed individually and no conclusive assumptions can be drawn.

2.3 Kondratieff Wave

The Industrial Revolutions are events that have caused a great deal of change to the world. The overall quality of life of the population tends to improve every time a big discovery is made that allows production of goods to be faster, cheaper and in larger quantity. These events usually take a few decades from their start to finish, and they all tend to have certain characteristic stages happening during and in between them. It was with this trend of repeating stages that researcher Nikolai Kondratieff used to build a theory, in which he proposed that the economy went through cycles. He also believed that the economic growth could be predicted, as well as, the development of tendencies. Later on Joseph Schumpeter perfected this theory and proposed the titled "Kondratieff Waves" to define this phenomena. These cycles were found to range from forty to sixty years in length, and where comprised

of periods of high economical and sectorial growth, followed by a period lower sectorial growth (Kondratiev, 1925).

In his original paper Nikolai Kondratieff analyzed the macroeconomic performance of England, France, Germany and the USA. For this analysis, he observed the prices of the wholesale products, interest rates and some other amounts, between 1790 and 1920. When examined, the data showed that in a long time period, the values seemed to have the same low and high points. With this statistical evidence we concluded that the economical process was one of continuous development and, pointed out a few explanations for these long waves, like changes in technology, wars and revolutions, appearance of new countries on the world map and fluctuations in production of gold (Kondratiev, 1925).

Schumpeter (1939) theorized that the external factors discovered by Kondratieff couldn't be sole reason for the changes that were happening to the economy, there should also be internal factors that were causing the deviations. The internal factors that Schumpeter found to be responsible for the "waves" were the state of the economy, political reasons and social factors. A part from this, he was the first to hypothesize that these waves could also be an occurrence brought on by big innovations that would affect the world's economy, most notably the Industrial Revolutions. To this point, the second Industrial Revolution was the proof of concept that he utilized to further credit his findings (Schumpeter, 1939).

Rolling 10-year yield on the S&P 500 since 1814 till March 2009 (in %, p. a.)

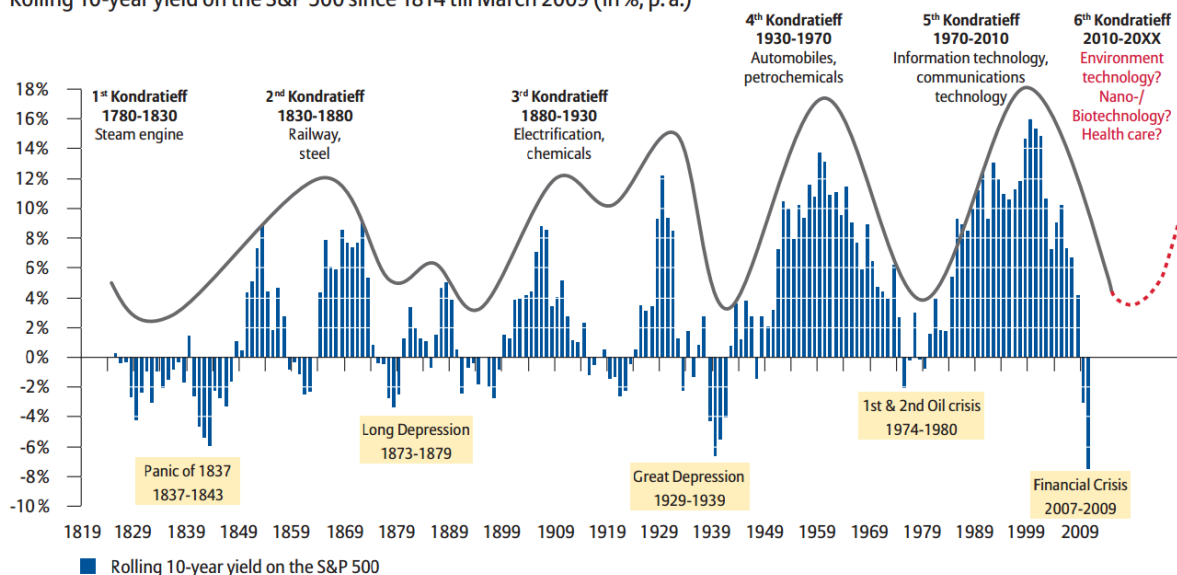


Figure 1 - Kondratieff wave cycles

Source: DataStream; Illustration: Allianz Global Investors Capital Market Analysis - The sixth Kondratieff – long waves of prosperity (January 2010)

The first wave took place between 1780 and 1830. These dates coincide with the first decades of the Industrial Revolution, which took place around 1760. During these fifty years the world's economy went through the four stages of the cycle. The fact that this innovation has effects throughout the whole world is due to, as we saw previously, it being a radical innovation. Therefore, it doesn't only affect the country and, or industry in which the innovation takes place, but since the effects are so immense the effects will be felt all the way in other countries and industries (Deane, 1979).

The Kondratieff cycle had initially three phases, expansion, deflationary growth and recession but later on was added a fourth phase, the stagflation, which is the turning point when the expansion stops, and it is followed by the deflationary growth. These phases seem to be similar throughout the different cycles and the changes won't only be noticeable in the economy, but through the population's frame of mind as well (Kondratiev, 1925).

In the expansion stage, there will be economical growth as well as an increase in innovation, accumulation and inflation, which will enhance the displacements within the society. In this phase is also common that workers will need to change their abilities to better suit the new

positions that are created via the innovations. This phase usually requires twenty-five years to be complete. After this initial phase, the economy will go into the stagflation stage, which is characterized by the shortage in resources, and as Roy Dutton wrote on his 2009 book *Financial Meltdown*, “*An economy will only support expansion to the limits of its resources, both human and material*” (Dutton, 2009, p.41). These periods usually are associated with the start of wars, such as the First World War or the Vietnam War. Because of these events inflation tends to rise, unemployment rapidly grows and outputs drop. This is the point in the wave cycle in which the perception towards the economy change, as well as, the whole structure. As a result to these new found limits in the economy, the population’s mood tends to alter, and their actions tend to be more conservative. This phase tends to be relatively short with a lifespan of three to five years (Dutton, 2009).

At the deflationary growth phase, the economy enters a period in which growth is relatively flat, which is still a consequence of the stagflation period. It is at this stage that new innovations will start to take place, as a result of the scarceness of resources, as well as, the ever-increasing prices. About ten years after the beginning of the deflationary growth phase, the economical markets will enter the final stage of the Kondratieff wave cycle, the depression. As a direct continuation of the previous stage’s innovations, investors will tend to explore those new alternatives, especially since the older technologies will start to give diminishing returns (between forty to sixty years into the cycle). This will start a period of radical change where newer technologies will be put to test, which will stretch out into the beginning of a new Kondratieff wave. Another aspect that marks the depression of a cycle is the abundance of financial capital compared to physical capital (Dutton, 2009).

The beginning of every cycle is usually accompanied by some big entrepreneurial endeavors making the initial phase of the cycle be considered has something famous, and we will take a deeper look into them in the analysis of the Industrial Revolution. But at the end of every one of these cycles there are always events that are well-known as well. The first one is now known as the “Panic of 1837” (1837-1843), and started because entrepreneurs of the time had collected huge debts in the hopes of paying them off by producing large quantities of goods, but as time went on, the cycle started to turn and the prices of the products started to decline making these massive debts unable to be settled. One of the industries that had a hard

crash during these years was the cotton industry. Cotton was previously, alongside with the steam engine, one of the building stones that brought the first wave cycle to life. But as time went on, the price of cotton went down, given that the demand for the textile industry was starting to decrease. And so there were massive layoffs at these textile companies, which led the backers of these companies to get concerned and cut-off their funding. This meant that the producers of the cotton weren't receiving any more money from their production, making them unable to pay-off their loans as well. With this predicament it wasn't only this industry that was in trouble, but since the whole economy was so well interconnected, the world's economy just stopped. This fallout tends to always happen at the end of every one of the cycles. The end of the second cycle was deemed the "Long Depression" (1873-1879), followed by the "Great Depression" (1929-1939), the "First and Second Oil Crisis" (1974-1980), all the way to the most recent crash, the "Financial Crisis" (2007-2009) (Kondratieff, 1979).

After each one of these wave cycles there are a few outcomes that can be expected, such as the introduction of new industries, which in some cases will be replacing old outdated ones. The companies themselves see some magnitude of changes within, either because they have a need for their workers to have new qualifications, their processes being altered or, probably one of the more difficult to outcome, the change in the company's culture (Freeman, & Soete, 1997).

There have been a grand total of five wave cycles throughout these last two centuries, being that the most recent example was associated with the information technologies (IT). This is, for most people given its proximity in terms of time, the example of how much the world can change during one of these cycles. Before the implementation of the IT, storage of data was only able to happen manually, and transmitting it was troublesome, making the process of sharing findings almost impossible, or in the least, harder to achieve. In the context of the manufacturing business, after the implementation of IT companies gained computing power making the whole manufacturing process easier and more profitable, since the usage of the resources was now being accomplished more efficiently (Jensen, 1993).

At this point in time, the Kondratieff long waves is a well-known and highly accepted by most theory. Most of this is credited by the fact that this concept can be easily traced by

historical data. But there are still some points in which doubts can be found. One of these points is the fact that researchers don't yet fully understand the exact driving force behind the initial phase of a Kondratieff wave, but most agree that the more reasonable explanation is actually the innovation leaps. Chris Freeman and Francisco Louçã, actually manage to correlate the start of the Industrial Revolutions, and to a bigger instance, the beginning of the Kondratieff wave cycles, to innovation. To accomplish this goal they utilize historical data on technological advances, economic structure, salaries, and political unrest. As such they pin point that the start of the five previous cycles are directly caused by water-powered machinery, steam power, electrification, the internal combustion engine and computerization (Freeman & Louçã, 2001).

Despite there still being those who doubt the veracity of the Kondratieff long wave cycles theory, the fact is that the main focus point of the long wave cycles has to do with the accumulation of debt and, that debt inevitably collapsing, and for these factors the historical proof seems to suggest that the theory actually is applicable. Therefore preparing for the inevitable worst is something that every company, and to a bigger instance, every country needs to be prepared. Since being active is always better than the proactive approach.

This brings us to the next Kondratieff waves, the sixth to be exact. Many speculate that this new wave is already in motion (Korotayev & Tsirel, 2010). The reasons that seem to prove this assumption can be found by comparing our current financial and social state, to the ones of the previous five waves (Allianz, 2010). For instance, we are now at a point in which the previous big innovation, the computer, doesn't bring a lot more productivity simply by improving it, since the technological upgrades aren't enough to make bigger results just by themselves. This is what happened right before the start of a new era in innovation with the previous long waves. Furthermore, as we previously analyzed, when there is an excess of financial capital compared to physical capital there usually is a financial crisis. Such an occurrence happened back in 2008, partially because of the U.S. real estate loans, and as such, we can mark that point as the begging of the depression phase of the long wave. Similarly to the this financial crisis was the 1930 financial crisis, also known by the Great Depression, which was also a turning point for the economy leading to the fourth Kondratieff wave (Dutton, 2009). So we can observe, in recent years, the downfall of the economical

market as well as the limitation of the technology that were once the beginning of the cycle. As such, it seems that we are in the point in which a new cycle should begin. This seems to be confirmation to the thesis that the Industry 4.0 might actually be the big innovation that would start the next Kondratieff wave cycle, making it an innovation worthy of being designated as the fourth in the line of Industrial Revolutions. Although this isn't definitive proof, the historical facts seem to be enough, to at least make this thesis worthy of being explored.

2.4 History of the Industrial Revolutions

The first Industrial Revolution took place between the 1760's and the 1840's, in Great Britain and the United States of America, and originated with the utilization of steam and water in the mechanization process. Factories that once needed a vast workforce to accomplish their goals, now only need a few machines and a fraction of the time. For the manufacturer this meant that their products could now be done in lesser time and more cheaply than before (Deane, 1979). This marked the beginning of the mass production, which would ultimately lead for the population to gain a new comfort in their lives, since they were now able to acquire products necessary for a standard of living (Fraser, 1973).

The first Industrial Revolution had a lot of improvements in the world, just like the average living standard rising, the growth of the average income, creation of new laws designed for an industrious society, augmentation of the city structures and the acquisition of new skills by the working force, this all meant that the population started to gain a new state of mind that would lend them the confidence to actively want to improve their lives (Freeman & Louçã, 2001). This can also be seen through the numbers regarding the world's population. In Europe the population in the 1700's was about 100 million and, by the end of the 1900's was above 400 million (Krishan, 2016). The same occurred all over the world, with population growing about 57% in the same span of time.

Right before the beginning of the second Industrial Revolution, circa the 1870's, the innovations that were being made with the first revolution's technologies were only slight improvements on already existing processes, with nothing too innovative being brought forth (Deane, 1979). And so, the second Industrial Revolution began, also being named the "Technological Revolution", and it reached all the way into the 20th century, 1914 to be more precise, the year that the first World War started.

Once again, similarly to what happened in the first Industrial Revolution, the second Industrial Revolution made it so production got faster and the final product had a better quality. What led to this was the utilization of electricity, petroleum and new production processes, like the division of labor and mass production. The factories now had available to them machinery that could function with increased automation, meaning that the amount of work needed to be done by people had decreased (Mokyr, 1998).

In the first Industrial Revolution it was textile that started to be mass produced, but in the second that mass production changed products and started to be steel that was now being mass produced. This mass production had such a huge impact on the world mainly due to the increasing number of railroads that were being built at the time, and the ability to produce steel at a faster pace really helped the connection of the world (Mokyr, 1998)..

The third Industrial Revolution would come around the 1960's, and was also known by as the "Digital Revolution" and, as the name suggests, this revolution has for its main characteristic the implementation of digital technologies, like computers and later on the internet, into the industrial processes. What this meant for the whole manufacturing industry is that by the implementation of these technologies the processes became faster and the overall quality of the products improved. With the implementation of computers, the people in charge of managing the organizations had now available to them, data that was generated throughout the different stages of the manufacturing process. This information would permit for the management to better apply their resources in order to optimize their production. The same can be pointed out for the implementation of automatous robots that would guarantee improvements in quality and would reduce the amount of waste created (Greenwood, 1997).

The effects of the third Industrial Revolution, in terms of improvement of the quality of living for the general public, would be very different from the previous two Industrial Revolutions,

meaning that those two revolutions had a positive effect reducing shortages of items that would inevitably improve the longevity of life in the globe, like food, clothing and health care, whilst the third revolution will certainly improve the quality of life once again, but in a new manner (Greenwood, 1997). For example, due to the development of computers and the internet, the population gained a new possibility to expand their knowledge and be able to entertain themselves in a whole new way. Globalization also benefited a lot from this Industrial Revolution, since it allowed people to spread their ideas and culture in a way that was previously thought impossible.

2.5 Industry 4.0

2.5.1 Introduction

It is no easy task trying to find a definition that will correctly characterize what is the Industry 4.0, since most characteristics of this new Industrial Revolution are owed to the technologies and processes components that are put in place. And there are a lot of technological components that allow the implementation of the Industry 4.0 to a regular production line, but some of the most notable are the Cyber-physical Systems (CPS), Cloud computing, Artificial Intelligence (AI) and the Internet of Things (IoT). These are what are considered all technologies that are required to automate the production process (Angelov, 2013). In this dissertation, we will be taking a quick look into these technological components, seeing that they are such an important point to the whole innovation process, but keeping in mind that this is a management approach to the subject, and not an engineering one.

All of the technologies that are here mentioned together with some organizational aspects are the characteristics that make the Industry 4.0, and subsequently allow the existence of the smart factories. Germany, the birthplace of the Industry 4.0 phenomena, is a well-known industrious country, with a vast history in this regard. But with the ever increasing number of competitors capable of having cheaper labor, the German government and organizations

sought to find a way in which they could maintain their market position. The overall quality of the goods and services that these countries manufacture is higher, but the costumers are less than willing to pay premiums for this quality (Brettel et al., 2014). As such, Germany decided to take a different approach, in the form of the Industry 4.0, which allowed product customization and faster time to market (Schweiger, 2011). Both of these characteristics are proving themselves to be very attractive to the costumers, either because of how fast fads go away and, sometimes the differences in days can cause serious shifts in consumer demands, and thanks to the virtualization process the sets in the production can be altered in a faster manner (Goldman, Nagel & Preiss, 1995). Or because the costumers can demand highly sophisticated products that will fulfill their needs perfectly, all this while maintaining the high quality and low mass production costs (Pine, 1993).

2.5.2 Cyber-Physical Systems (CPS)

Cyber-physical Systems (CPS) are considered as an intrinsic technology to the fourth Industrial Revolution, but what are its characteristics. CPS is an integration of computation with physical processes (Lee, 2008), meaning that these systems provide a world where the virtual and physical spaces are linked, which allows a better communication between the both. To achieve this objective they tend to make use of RFID (radio-frequency identification) chips, that when attached to every machine and materials can help to identify themselves, their respective tasks, conditions and where they'll need to be to make production more optimal, further allowing this ideal of a metaphysical world being observed through a computer. Sensors, data acquisition systems and computer networks in the last few years have become more affordable, which has allowed for this integration to have happened (Lee, Bagheri, & Kao, 2015) Siemens, which is one of the companies that is intrinsically interconnected to the whole Industry 4.0 phenomena, is very well known for the integration of RFID chips in their production lines, and according to their reports it seems to improve the overall manufacturing process (Finkenzeller, 2010).

The opportunities that arise from the implementation of CPS in production of goods and services are plentiful and, benefit not only the manufactures, as well as, the end consumer.

But seeing that this type of service is relatively new, there are some aspects that aren't well optimized yet. For example, for there to be an optimal utilization of the CPS, both software and hardware need to go beyond the technological state in which they are now (Baheti & Gill, 2011).

2.5.3 Artificial Intelligence (AI)

Artificial intelligence (AI) is a concept that has been explored ever since the primordial days of technology. It refers to the type of intelligence originated from computers that we consider as cognitive, mainly meaning that it can solve problems and learn from past experiences (Russell, et al., 1995). With these "human like" capabilities, many researchers await with high expectations the new possibilities that can become a reality in the future. Since the most likely outcome for the Industry 4.0 is actual machines that don't require human management in all the menial tasks, having the capability to assess the best possible way of reaching the goal, in other words AI, I think it is necessary to do a brief analysis of what are the actual real life applications of this technology.

AI is making concepts like self-driving cars, "Smart cities" and, more related to this dissertation, "Smart factories", a reality that can be achieved in the near future. Smart cities, is the name that is given to a city that has its operations (water supply, waste disposal, food supplies, urban traffic management, etc.) being dealt by a system of AI that will make the optimal decisions in regards to efficiency. The same can be said by self-driving cars, efficiency is one of the big selling points of this usage for AI, either in terms of fuel consumption, pollution reduction or reduction in crashes, with the latter being said to drop by 90% with the elimination of human error (KPMG 2012). These examples just show how much human lives can be improved through the help of a system that whilst resembling human intelligence, far surpasses it by making human error obsolete. This is a big selling point when referring to the Industry 4.0. Since AI is ever learning and can predict outcomes based on statistical data, whilst reducing possible negative outcomes, it is the perfect system to be in charge of a production line or any other type of facility that would be functioning with a high amount of data collected (Dopico et al., 20106).

2.5.4 The Internet of Things (IoT)

The Internet of Things (IoT) is another technology that is vital when discussing the industry 4.0, just like CPS and the AI. IoT serves as a sort of glue that connects the different sensors, actuators and other technologies to interact with each other and achieve a common goal (Giusto, 2010). This connectivity isn't limited to an infrastructure and enables the user with remote control, cutting down on dislocation fees and manpower (Santucci, 2010). But this technology goes beyond the factory usage, since it can be applied to everyday appliances and even vehicles. It is estimated that by 2020 more than 50 billion objects will be connected via the IoT (Evans, 2011). This can give a lot of context to this technology, being that it will be imbedded into the lives of a huge portion of the population in the not so distant future.

This ability to be able to control the physical world at a distance isn't only useful for the everyday life of the population, it's the abilities in factory and production environments that will be vital when discussing the fourth Industrial Revolution. As previously mentioned, thanks to this technology there will possibly be cuts in the workforce, since the machines can be operated at a distance, or even operate themselves thanks to AI (McFarlane, et al., 2003). But there are other characteristics such as, organizational improvements, maintenance, diagnostics of machines and products, just to name a few (Ashton, 2009). The possible savings associated with these changes are vast, as such, it appeals to a large amount of companies, although the improvement costs might be a little steep at first, the savings through the years would more than compensate the investment.

2.5.5 Cyber Security

As it was previously discussed there are a lot of technological components that make the Industry 4.0 possible, CPS, AI and IoT, just to name a few. But all this emphasis on the technological aspect of the Industry 4.0 has many concerned for the security of their enterprise, mainly due to the fact that cyber security is something that isn't perfect. Obviously

each company can decide on the level of security they want to implement, but sometimes even the most efficient security on the market can be broken, leaving the company exposed. This exposure can lead to the destruction of hardware and software, the theft of information or even the disturbance of the normal procedures.

When discussing the concept of IoT we saw that, thanks to it and some other tools, systems are now able to interact with each other in a more easy way (Ashton, 2009), but that easiness can also mean the creation of breaches in which the systems can be compromised by third parties (Al-Fuqaha, et al., 2015). This is a big threat to the worldwide implementation of the Industry 4.0 and the smart factories, since a big part of how they work is due to the interconnectivity. These third parties, or so called “hackers”, have a large skillset that allows them to gain access to other people’s computers. Once access is gained, they are able to exploit those devices. The international security company Gemalto has found that between 2004 and 2013, over one billion records of personal information were either stolen or leaked, but what is even more shocking is that in 2014 alone, there were the same number of leaks as they were between a span of nine years (Gemalto, 2016). So we can conclude that the “hacking” problem is aggravating and could very well be a thorn in the Industry 4.0 ascension.

When organizations gets compromised in this manner it can have different consequences, like the stealing of their most confidential information. This is just one of the many forms that industrial espionage has been taking in these last few years (Nasheri, 2005). And because of this threat it is only natural that organizations get concern about this possible breach, since there have been cases in which industrial espionage has been the cause for the shutdown of organizations (Byres & Lowe, 2004).

In the case of organizations, the intellectual property can include, ideas, techniques, processes, recipes, formulas, know-how, pricing, sales, marketing, research and development, amongst others. And when it comes to which industry is more likely to be targeted for industrial espionage, although every single industry can have this problem, the ones that are likelier to have this happen to them, are the ones with a heavy influence of technological advancements and, therefore a large amount of R&D investment, like for example the aerospace industry, computer hardware and software development and even the

pharmaceutical industry (Nasheri, 2005). To show the gravity that this situation might have, in 2009, Walter Opfermann who is an employee for the German government, disclosed in an interview for The Guardian (22 July 2009), that every year due to industrial espionage companies were losing around €50 billion and over 300 thousand jobs (Connolly, 2009). And this isn't the only case, every country in the world is being affected by hackers, and there isn't a definitive solution to prevent these actions. To this matter, there were created various agencies that try to deal with the cyber security, like the ENISA (European Union Agency for Network and Information Security), European Cybercrime Centre which is a part of Europol, and CERT-EU (permanent Computer Emergency Response Team) (European Parliament, February 2016).

So with all the information here presented it would seem that the cyber security is a pressing matter to the Industry 4.0 (Singh et al., 2016), in the way that it might possible be a deal breaker to some companies that were considering it (Intel IT Research 2012). It's also true that all organizations are open to malicious parties, since almost, if not all companies have some connectivity to the internet, not to mention the possible breaches that are possible in the physical world, but the Industry 4.0 has an even heavier usage of the Internet and other systems that can be abused remotely (Von Solms & Van Niekerk, 2013). And so, this is definitely an aspect of the Industry 4.0 that needs to be further developed, with a need for a constant update of both software and hardware, in order for the organizations to have one less concern when pondering in adopting the Industry 4.0.

2.5.6 Waste reduction

One of the aspects that is constantly being referred as one of the beneficial points of the Industry 4.0 is the reduction, or even extinction, of the wastes that normal manufacturers have to deal with. These wastes occur naturally when producing any goods or services and, can differ depending on the company and the industry. But what they tend to have in common is that they don't give any value added to the final good or service. In 1988 Taiichi Ohno, who was a mechanical engineer at Toyota, credited with the creation of the Toyota

Production System, was able to identify seven kinds of waste that were shared between all manufacturers (Ohno, 1988). These are the 7 wastes of production:

1. **Defects** – Defects represent an incredible expense to the organization, since their costs go beyond the materials that are wasted in the production process. Organizations will have to account for re-inspection, logistic, capacity loss, and if the damaged goods manage to be sold to the final consumer, there will be costs with exchanges, possible lawsuits and the brand will suffer bad publicity.
2. **Over-production** – This type of waste tends to occur when the production of a good happens before the need for said good arises. This type of waste is considered to be the most expensive that an organization could have, since it will lead to increases in storage costs, diminish quality, reduce productivity and it will make the screening for defects more difficult. In a way this defect will amplify the remainder wastes.
3. **Waiting** – Every time a good sits idle without being moved or worked upon is a representation of this waste. For example, when a machine isn't being used because it is waiting for resources, or the opposite, when the resources aren't being utilized because the machine isn't ready.
4. **Transportation** – This doesn't, in any way, augment the value of the product, it can in fact devalue the product if the transportation is carried out excessively and with poor care.
5. **Inappropriate Processing** – Occurs when the production used isn't the most optimal one, either because it is sub-par when compared to other processing techniques, making the overall quality of the product less than what it could be, or because on the market there are other production processes that are more economically viable compared to the existing one.
6. **Unnecessary Inventory** - When there is a surplus of inventory there are some costs that will emerge, for example the extra storage costs, possible spoilage of the goods or even the fact that the goods can be outdated whilst in stock. This waste is directly interconnected with the over-production and waiting. Assessing the demands of the consumers before the production starts is a good way to prevent this waste from occurring.

7. **Unnecessary Motion** – It refers to the excessive movement that the personnel have to endure to accomplish their production goals.

These are just the wastes that are common between all production lines, manufacturers still have to account for the wastes that are specific to their organization. Therefore, wastes are an expense that affects all organizations and their significance isn't small (Maskell, B. H., & Kennedy, F. A. 2007).

With the elimination of wastes there are other areas besides the financial profits that will improve. The environmental affect that the company will have will also decrease, given that less waste will mean less resources consumed. Just to put this issue in perspective, in the year 2000 it was estimated that 76 billion tons of industrial solid waste is created yearly (Vanatta, B. 2000). The overall public perception of the organizations would also benefit from it being considered as a "green" company, possible benefit from tax cuts, depending on the country (Shah & Ward, 2007).

When Henry Ford in 1913 applied the assembly line to his factory, he began to see improvements in the time that it for the manufacturing process to be complete. The moving assembly line is a good example of a way in which reducing wastes, in this case the time that it took workers to walk between the different manufacturing stages, as well as, the time spent in the transportation of the unfinished product (Krafcik, 1988), can lead to high levels of success, since Ford, thanks to this method, made the most sold car of that period, the Model T.

It's hard to exactly quantify the amount that an organization will spend yearly with wastes, since these are so imbedded in their regular operations, that even they might not know the exact value. A recent study by PwC (Geissbauer, et al., 2016) as revealed that companies expect to save up to 3,6 percent yearly, with the transition to the Industry 4.0. This value makes it very clear why the Industry 4.0 promise of reducing wastes has so many organizations intrigued (Sanders et al., 2016). A cost reduction of that size can make a lot of companies profitable, where they once weren't.

2.5.7 Differences between factories and “smart factories”

Much has been said so far about the technological components that will be a part of the Industry 4.0, as well as what are their benefits and draw backs, but we have yet to discuss the effects that the Industry 4.0 will have on the way that organizations are managed. Therefore, this next segment will serve as a way to try and foretell how these “smart factories” will differ in management from a regular factory. We will take a look at how the extra machines will differ, the qualifications that the managers will look forward in an employee and the difference in costs.

Human resources management is an essential area to every business, since these managers are in charge of hiring, supervising, managing the company’s culture, dealing with issues, motivate and sometimes, training the employees (Guest, 1987). These employees are a part of an organization’s business resources, alongside knowledge, financial and physical capital, and their function is as important, if not the most important, as such special attention must be given to their needs (Huselid, 1995).

In the book “*Organizational culture and leadership*” by Edgar H. Schein, it’s discussed the relevance and impact that a good organizational culture can have on the overall profit and appearance of an organization (Schein, 2010). As such, the human recourse managers that are in charge of this aspect of a company, will always need to be focused on what are the best ideals and morals for the workers, showing just how important their functions within the company really are. They will need to always be thinking of future necessities and be able to diagnose the status of their organization (Hersey & Blanchard, 1993). Now if we take into account the differences between a regular factory and a smart factory, it isn’t hard to imagine that the human resource aspect of running an Industry 4.0 factory will strain from a regular factory, especially if we take into account the amount of extra technology that comprises a smart factory. As such, and since most of the menial tasks will now be realized by machines, it’s only normal that the demands for unqualified workers will be reduced and, once again given the extra machinery, more workers with engineering and IT qualifications will be in high demand. Areas related to the science, technology, engineering and mathematics are

some of the more likely to be in high demand for the smart factories (European Parliament, February, 2016). But with this said, it is still very early to define the job demands of the Industry 4.0, given its short life, and the fact that there are still few organizations that are implementing these technologies, there might still arise job descriptions that today still don't exist.

Jobs in departments like management, marketing, accounting, human resources, are less likely to be taken over by machines, since there are still tasks that are more effectively accomplished by humans, like approaching a problem in a creative manner (Hecklau et al., 2016). The fact that the departments that will need workers with more elaborate knowledge other than the ones that they already possess, doesn't necessarily mean that they'll need to hire a completely new staff, mostly because that would have catastrophic repercussions in the organization's culture, plus the negative effects in the loyalty and public image. As an option, companies can opt to invest in their workforce's education, and prepare them to the Industry 4.0 demands (Hecklau et al., 2016).

Countries will have an important role regarding the education of their workforce if they want to be accommodating to organizations investing in the Industry 4.0 (Smit et al., 2016). Like it was mentioned above, the Industry 4.0 is a new phenomenon, which means that there are still some aspects that aren't fully developed, in this case, the curriculums needed in order to satisfy the future needs to the fourth Industrial Revolution (Hecklau et al., 2016). What this will mean for the future, is that the success of the Industry 4.0 is directly linked to a country's ability to educate their population in accordance to the needs (Federal Ministry of Economics and Technology, 2010). This is a debate that is already preoccupying governments, with a study by the European Commission saying that by 2020 there will be a deficit of 500.000 specialized workers in the European Union (European Commission, June 2016).

Just like in terms of the education, countries will have to be willing to aid the companies in the adoption of the Industry 4.0. This help can come in the form of tax benefits, encouragements for the creation and innovation of new processes or even founding to help smaller enterprises acquire the necessary technological components needed for the implementation of the Industry 4.0. This last point will be, for most business, the focal point that determines if they actually do, or don't, integrate the Industry 4.0 into their business.

The processes used in the smart factories will require machinery with higher technological components compared to the machinery used for a regular factory floor, these will no doubt have higher costs than the regular ones (Geissbauer, et al., 2016). This increase in value might be enough of a barrier, as to many companies not being able to afford them on their own, but if the governments have in place special aids for these cases, the Industry 4.0 might have a deeper penetration in the different markets.

Countries that have a large industrial sector are the ones that should be more proactive in trying to accommodate this change. Taking Germany as an example, since they are the largest manufacturer in Europe, according to Eurostat, their GDP is constituted by 22 per cent manufacturing and industry related enterprises, as well as, having more than 15 million workers employed by those sectors. It's no wonder that they were the birthplace for the Industry 4.0, given their desire to keep their country's business relevant. In accordance to a study that aimed to analyze the possible effects, that the Industry 4.0 could have to Germany, conducted by The Boston Consulting Group (Rüßmann et al., 2015), it was found that there will be four areas that will benefit from these technologies:

1. **Productivity** – With the new technologies, it's assumed that companies will be achieving productivity improvements on conversion costs from 15 to 25 percent, excluding materials costs, or 5 to 8 percent considering material costs. These improvements will lead to new companies joining the manufacturing industry, which will improve the overall productivity of the sector. It is estimated that during the next five to ten years the productivity across German companies will boost from between €90 billion to €150 billion.
2. **Revenue Growth** – The additional revenue will represent an extra €30 billion per year, which is around 1 percent of the German GDP. This extra growth will be achieved by the demand of higher quality and customized goods, as well as the demand for the enhanced equipment, data analysis and application software, with the goal of spreading the Industry 4.0 to other countries.
3. **Employment** – It is expected that by the next ten years the employment levels will grow 6 percent, due to the extra growth of the manufacturing sector. It is also mentioned that eventually the number of low-skilled labor will decrease, due to the

automatization of the factory floor, and there will be an increase demand for qualified labor, mainly in the mechanical-engineering and IT departments.

4. **Investment** – The investment required for the German companies to incorporate the Industry 4.0 to their production lines, or even the creation of new companies that will utilize these technologies, will require an estimated investment of €250 billion, until 2025.

This extra growth that Germany will experience until 2025, will help to motivate other countries, that otherwise might be skeptical of the Industry 4.0, to make the move and they themselves adopt the technologies, in the hopes of achieving some good results as well, or even just not to stay behind their competitors.

The supply chain is a big aspect that will differ in the smart factories. This concept refers to the process that every good and service go thru, from its raw material phase all the way until it is in the hand of the final consumer. This encompasses all the processes like design, transportation, storage, manufacturing, and it's the supply chain manager's job to plan out the demands in order to have enough stock, but not too much as it would be a waste, having in mind the needs of the costumers and making a profit for the organization, whilst still managing to sell the goods at a price that it will be appealing to the consumers (Handfield, 1999). As such, having a good supply chain management is extremely important to having an organization that is as profitable as it could be.

It isn't hard to imagine that the whole supply chain is a very intrinsic and complex system, but with the improvements that the Industry 4.0 will bring to the technology that encompasses a factory, the whole supply chain will most likely be more easily managed (Wang, C., & Yu, W. 2006). The fact that the value chain will improve will also benefit the rest of the decision making of the organization, allowing the customers faster response to their demands as well as a better communication of the needs to the suppliers and partners. This decision making process is benefited by the autonomization and learning of the machinery, that utilize CPS, IoT, AI and cloud computing, as we previously discussed, which allow for a reduction in the processes that involve human workers. It is thanks to these improvements that suppliers can be more easily aware of the material demands, and customers can request what they want in a product with more customization and in a faster manner (Schweiger, C. L. 2011).

In the paper “The impact of Industry 4.0 on the Supply Chain” by Hans-Christian Pfohl, Burak Yahsi and Tamer Kurnaz, it’s discussed the impact that the Industry 4.0 will have in regards to the supply chain, using the Leavitt's Diamond as a model (Pfohl, et al., 2015). In this theory there are considered to exist four components inside every organization that will measure the likelihood of success when there are changes, those four components being: people, task, structure and technology (Leavitt, H.J., 1965). In their analysis they found that out of the four components, it’s the distribution and structure the ones that will be more impacted in regards to the Industry 4.0, mainly because of the implementation of technologies that allow autonomization and learning. Therefore the success of the Industry 4.0 will largely befall to the way that organization are able to deal whit the technological upgrades, and the increase integration of said technologies in their supply chain.

As previously mentioned smaller companies will be the ones that will most likely have a harder time integrating the Industry 4.0 in their production lines. These so-called small and medium enterprises (SMEs), which are characterized by the Official Journal of the European Union as: “...enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.” (OJ L 124, 2003, p. 36), will have to reshape their complete supply chain, as well as their company culture, in order to adjust, and as we saw previously, this is a process that is long and costly, especially when there are a still vast number of enterprises that conduct their business with minimum to non-technological involvement. To these companies, the costs of digitalizing their whole supply chain might not make financial sense, even more when we consider costs such as the expenditures that are associated with the cyber-security, which is needed to protect themselves and the rest of their partners. There is also the possibility that the present staff that is employed by the SMEs isn’t qualified for the extra technology, since there isn’t necessarily a demand for that kind of expertise in their current situation. As such, the prevail of the smart factory effort will once again be dependent on the awareness and preparedness of the firm’s home country (Brettel, et al., 2014), this because of the possible contributions to the small enterprises, given by the nation, in order to upgrade their supply chain, as well as the training of the population.

In the research paper “Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0” (Kagermann, et al., 2013), the researchers explore a survey conducted by the professional associations BITKOM, VDMA and ZVEI, with a sample group of 278 companies, in which they try to access the trends of the Industry 4.0.

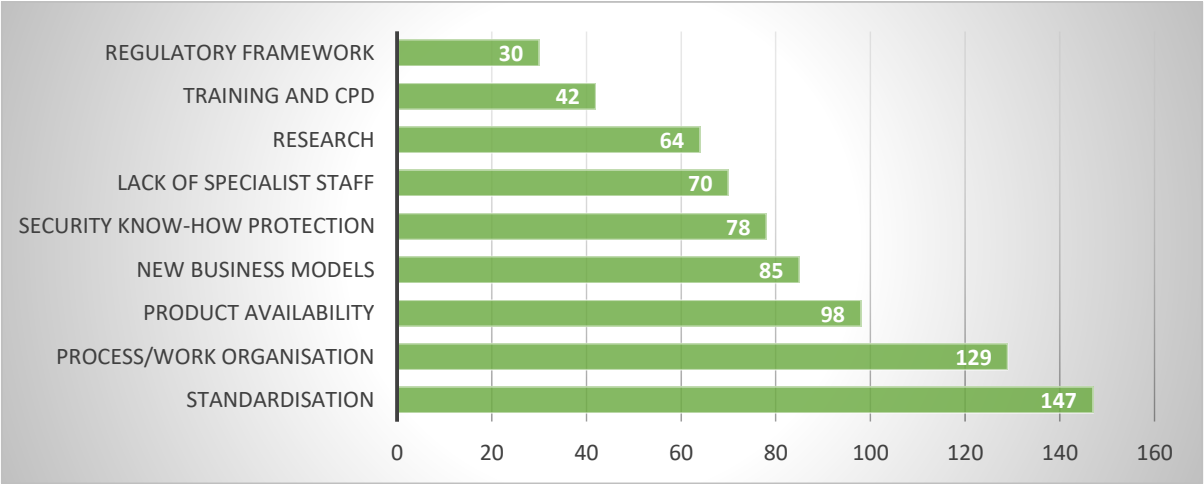


Figure 2 - What are the greatest challenges connected with implementing Industry 4.0?

Source: Kagermann, H. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0. - BITKOM, VDMA and ZVEI

Amongst the information, it was analyzed which were the challenges that could arise from the implementation of the Industry 4.0, said information is reflected in the figure above. The most notable challenge seems to be associated with the concept of standardization. This concept refers to the creation of a technical standard, that is, the establishment of a uniform way of engineering, methods, processes, systems, protocols and practices amongst the different firms that interact with each other, this will allow the maximization of the compatibility, quality and repeatability (Xie, 2016). This ideal is in fact a very important aspect to the success of the Industry 4.0 in general, with its importance being in display in the European Commission’s web site:

“Standardisation has played a leading role in creating the EU Single Market. Standards support market-based competition and help ensure the interoperability of complementary products and services. They reduce costs, improve safety, and enhance competition. Due to their role in protecting health, safety, security, and the environment, standards are important to the public. The EU has an active standardisation policy that promotes standards as a way to better regulation and enhance the competitiveness of European industry.” – European Commission (22/01/2017) Retrieved from: https://ec.europa.eu/growth/single-market/european-standards/policy_en

This concept of standardization will also be very dependent of the willingness of the adoption of the Industry 4.0 business model by the SMEs. Big companies will, more often than not, have smaller firms within their supply chains (Bowersox, et al., 2002), and since standardization is as such an important aspect of the Industry 4.0, the whole supply chain must be operating on the same standards, in order to make the processes as efficient and cost saving as possible. The benefits of adopting the smart factory business model will, in the long run, be a sound business endeavor (Geissbauer, et al., 2016), but the cost of upgrading the operation to standardize with the rest of the supply chain might be beyond the possibilities of the SMEs (Brettel, et al., 2014). This might be one of the reasons why the standardization is the biggest challenge in the point of view of the investors, since the possible success of the Industry 4.0 implementation is beyond the control of their own company, and therefore an unpredictable variable.

All of these remaining challenges of the study (Kagermann, et al., 2013), as well as, standardization, have the same origin point, and that is the uncertainty that arises from the creation and implementation of new way of managing the production of products and services. Uncertainty and skepticism are qualities that a good manager needs to have in order to protect their business. A vast number of managers will need some time in order for them to truly understand and trust the Industry 4.0, before changing their whole supply chain.

Mass customization is an especially big talking point when it comes to differences between regular and smart factories (Brettel, et al., 2014). This concept refers to the goal of allowing each customer to be able to acquire the exact goods and services that they desire, with certain

characteristics that best suit their needs, whilst still having the same costs and quality as if those goods and services were created by a mass production process (Pine, 1993). Previously, in regular factories, this was a nearly impossible task, given that the logistic systems couldn't handle the customization of every one of the multiple customers, but with the introduction of the Industry 4.0 both the supply chains and the logistical systems have been improved to the point in which mass customization could be a possibility (Brettel et al., 2014). This high emphasis on mass customization comes from the high levels of competition that exist in the manufacturing industry. By this method, companies can maintain their high levels of quality, while making customer-centric products (Moser, 2007).

2.5.8 Overview

After this extensive analysis to the vast intricacies of the Industry 4.0, we can observe that its implementation is something that is a possibility and that could prove itself as a benefit not only for the organization, but to the hosting country as well (Rüßmann, et al., 2015). This fourth Industrial Revolution has very deep ties with the technological components that are in use (Angelov, 2013). Either it would be the CPS, the IoT, the AI, amongst the other, the smart factories cannot function to their full potential without all of these technological components working together in synchronization. To this case, the possible matter of the Industry 4.0 longevity is deeply interconnected with the promise, and hope, that there will be third parties that will continue to improve the technologies (European Parliament. February, 2016).

The success of the Industry 4.0 can also be tied to the awareness, preparedness and ability to be embraced by not only the companies, but by the countries themselves (Buhr, 2015). A study conducted by Deloitte into a sample of Swiss companies (Deloitte 2014), has showed that although their manufacturing industry seems to be conscious of the increased competitiveness achieved by adopting the Industry 4.0, only a few of those companies perceive this increase as significant enough to make an impact on their current business. The availability of a specialized workforce can dictate if a country's will be able to fully benefit from the smart factories, as such, this is another matter that will be intrinsic. But beyond

recognitions, awareness and having the right resources available, there are other matters that will dictate the possible workings of the Industry 4.0 when referencing the host country, like policies, security for the supply chain's information and support for the SMEs.

It would seem that there are a vast number of variables that need to be accomplished in order to further facilitate the implementation of the Industry 4.0. These variables are sometimes beyond the reach of what the company can achieve by itself, since there will have a necessity of business partners that are able to deal with the extra demands, as well as, a country that is acceptant of the implementation of the Smart Factories. And yet, the possibilities of what the Industry 4.0 can achieve for an organization, appears to outweigh all the perceived obstacles that the same poses. Either it will be by the reductions obtained by diminishing the wastes (Geissbauer, et al., 2016; Sanders et al., 2016), the gains achieved by the increase in productivity, the extra sales numbers gained from the increase in quality or even the market gains from the extra customizations options that the company will be able to offer its customers (Brettel, et al., 2014), or at a macro level, the gains to the economy from the stimulation of the production and manufacturing industries (Roland Berger, 2016; Geissbauer, et al., 2016), alongside with the extra jobs that will emerge (Roland Berger, 2016). The fact of the matter is that the benefits of the Industry 4.0 seem to prove that its implementation is a good solid investment. And yet, this analysis is still only based on other researcher's findings, to have a clear and objective result the best possible source of action is to do my own market analysis of the Industry 4.0, more specifically an analysis into the awareness and acceptance of the Smart Factory trend in the Portuguese market.

3. Research Model

In regard to the research portion that was created for this dissertation, the objective was to try to analyze the possible preparation that a specific group of companies would have in adopting the Industry 4.0. As such, a model that would have the broad objective of gathering the level of preparedness that a certain group of companies have towards the Industry 4.0 was devised. This model was created thanks to the knowledge that we gathered during the previous stages of this dissertation, in which we took a deep look into the different characteristics and intricacies of the smart factory phenomena. The model will be comprised by three different dimensions that, combined would allow the analysis of the possible readiness of the companies in regard to the Industry 4.0.

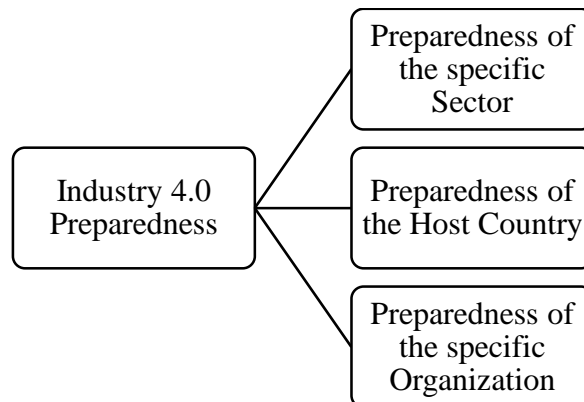


Figure 3 - Representation of the Index

The first dimension that will be a part of the “Industry 4.0 Preparedness Index” is entitled “Preparedness of the specific sector” and, in this element there will be eleven questions that will determine the company’s confidence level in their own sector of activity towards a good adoption of the Industry 4.0. Matters like the adaptation of both suppliers and clients are some of the analyzed aspects in this first dimension.

The second dimension (preparedness of the host country) will ascertain the effects that the different companies assume that the host country will have in influencing the adoption of the Industry 4.0. This dimension refers to matters like the confidence that the company has on the country to help with the transition to the smart factories, as well as, the willingness of the country to adopt learning programs that will meet the future needs of the Industry 4.0. This dimension is composed of four questions.

The third dimension (preparedness of the specific organization) will be directly linked to each specific company, since its objective is to determine the level of preparedness of the specific organization into to adopting the Industry 4.0. To accomplish this goal, seven questions were constructed. Matters like the future education of their workers and R&D investment are here analyzed.

As such, the model that would lead to the overall quantitative measure if a group, or a specific organization, is or isn't, prepared for the Industry 4.0, was formed. This model has a total of three dimensions (Figure 3), with a grand total of twenty two questions that will introduced to a vast number of companies, with the hopes of gathering a sample that is both big and has a good diversity of business areas.

3.1 Hypothesis

From the literary review made previously, we created four hypotheses regarding the main theme of the Industry 4.0 and using the Portuguese companies has an analyzing platform.

- H1: The Portuguese companies will score above the average (>50%) in the preparedness index;
- H2: Companies that conduct business with other countries (exportations) will score higher values in the preparedness index;
- H3: Companies that have a higher knowledge in the Industry 4.0 will have higher results in the preparedness index;

- H4: Companies that operate in business areas that are more likely to be early adopters of the Industry 4.0 (manufacturing, molds, etc.) will have higher results in the preparedness index.

To validate these five hypothesis, an index was created with the objective of judging the preparedness of the companies inquired. This index has three major variables, with all of them weighing the same amount (1/3), and each of these main variables are assembled with various questions that form an overarching theme. These main themes are “Preparedness of the host country”, “Preparedness of the specific sector” and “Preparedness of the specific organization”. The mean value of these three variables will be source of the “Preparedness Index”.

$$Preparedness\ Index = \left(\frac{A_1 + A_2 + \dots + A_n}{n} \right) * \frac{1}{3} + \left(\frac{B_1 + B_2 + \dots + B_n}{n} \right) * \frac{1}{3} + \left(\frac{C_1 + C_2 + \dots + C_n}{n} \right) * \frac{1}{3}$$

4. Methodology

For the empirical portion of this dissertation, the objective was to observe the level of preparedness that companies have in regards to the implementation of the Industry 4.0. To accomplish this goal, an online questionnaire was created that lead to the production of an index that would score the Industry 4.0's likelihood of success in a specific company, an industry or even a whole country. In this dissertation, we will be focusing in applying this index to Portugal. Besides the index, in the questionnaire are also questions that will allow for a further analysis to some specific characteristics of the companies, like age, sector of activity and investment in R&D, amongst others.

4.1 The selection of the sample country

The selection of Portugal as the case study for this dissertation, happened due to some factors, convenience being the biggest. Despite that, we think that Portugal can actually be an interesting case study, since in terms of technological improvement Portugal has been steadily raising its standard (Gibson & Naquin, 2011), as such, it can be a good example of a country that is gaining momentum in the race towards automatization. The perception aspect of this country can also be interesting to observe, since Portugal is a small country with not huge manufacturing industry, it is only natural that other countries would perceive Portugal has a just that. But I'm also interested in seeing what the Portuguese companies perceive of themselves, either as the rest of the world sees them or do they think of themselves as being capable of leading the fourth Industrial Revolution.

Portugal, in regard to its manufacturing values, according to a report done by Deloitte concerning the "Global Manufacturing Competitiveness Index" (2016), was ranked number 35 out of 40 countries. The manufacturing industry in Portugal was estimated at around \$23.8 billion in 2013, which represents 12.7% of the national GDP (Deloitte 2016). As we explored

previously, the manufacturing industry will be one of the most effected industries by the developments of the Industry 4.0, and given the values that this industry has in Portugal, it is only natural to assume that the future of the Industry 4.0 might be directly linked with the future of Portugal.

In a report by a German based consulting company, Roland Berger (Roland Berger 2014), regarding the possible outcomes of the implementation of the Industry 4.0 in Europe, Portugal was considered, in a part of the study concerning the readiness of the country, as one of the countries that would be more hesitant to the adoption of the Industry 4.0. In this analysis, they utilized two scales to determine the cluster in which every country would be more fitted. These scales are the “RB Industry 4.0 Readiness Index”, which is calculated using values for production process sophistication, degree of automation, workforce readiness and innovation intensity, and the other scale is the “manufacturing percentage”. With these two scales the authors draw a four quadrant area matrix, in which each of the four areas are associated with countries that are either “Potentialists”, “Frontrunners”, “Hesitators” or “Traditionalists”. The implications of being considered as a “Hesitator” country in this analysis, is that Portugal, and the rest of the other countries in this category like Italy, Spain, Estonia, Poland, Croatia and Bulgaria, are considered as not possessing a solid infrastructure to support the changes needed, mainly due to problems of the fiscal matter, as well as, not being considered as having a reliable industrial base.

This notion that Portugal might not be a frontrunner country in the early adoption of the Industry 4.0 might be worrisome. In matters of accepting and encouraging organizations to being part of the early adoption of new technologies, most times it is advantageous for countries to be supportive of the companies and help them, for example, by helping the SMEs making the change to the new technologies, in order to put their country’s market in front of the other countries. This lead might be the difference between being in the forefront, developing new concepts and technology, that will later be considered as a competitive advantage and will largely benefit the country, or in the other hand, if the adoption comes at a time in which the other countries already have a solid grasp on the processes, innovation and the benefits that come from it, will be nonexistent, and Portugal will most likely be left to only acquire licenses from other markets.

It appears that the Portuguese government is aware of the Industry 4.0's significance and its implied potential in helping the country's economy growth. This because the government has already put into motion plans to help SMEs make the leap towards the technologies that will be standard in the smart factories.

In the initiative "Portugal i4.0" (2016) retrieved from <https://www.industria4-0.cotec.pt/programa/medidas/>, the Portuguese Ministry of Economy identifies three main objectives towards the Industry 4.0 success:

- Accelerate the adoption of technologies and concepts of the Industry 4.0 in the Portuguese business fabric;
- Promoting Portuguese technological companies at an international level;
- Making Portugal an attractive pole for investment in the Industry 4.0 context.

The Portuguese government has already disclosed that they are prepared to invest up to 2.26 billion Euros in incentives towards matters related to the Industry 4.0, such as helping the SMEs or developing projects to develop new models and technologies.

They also plan to improve upon the qualifications of the workforce, both by planning for future curriculums, in which there will a bigger support for the IT areas, as well as further educating the already active workforce by having certain workshops and extracurricular courses that lean on the more technological route (Deloitte, 2016).

These points go towards the idea of success in the Industry 4.0 that was theorized previously in this dissertation. But another interesting point to gather from the Portuguese organizations is whether or not, if there is a trust in the Portuguese government to help them create and improve the smart factories in Portugal.

4.2 Data collection process

As it was previously mentioned, for this dissertation an original online questionnaire was created, utilizing Google docs, which would allow the characterization of a large sample of Portuguese businesses regarding the Industry 4.0, as well as, creating an Industry 4.0 readiness index.

The decision to utilize an online questionnaire came from the want to inquire the largest amount of businesses all across the country directly, getting a diverse sample in terms of business areas, as well as, getting the feedback preferably from someone up in the hierarchy, as such, the online survey was the best possible solution, given its low costs to accomplish, increased number in responses and automatic organization of the answers. On the other hand, there are some problems in this method of gathering data, as experienced, like false responses, not being able to choose the best population, and the email data base being outdated.

The questionnaire that was used to aid the analysis of the Industry 4.0 in Portugal can be found in the annex. But for full disclosure, the original questionnaire was elaborated and sent in Portuguese, as such, there might be some phrasing that will be more eloquent than the translated English version. Never the less, the essence of the questions, as well as, the responses, maintain their integrity. This questionnaire can be found in its entirety in the Annex I.

The data bases used to contact the different Portuguese organizations was kindly provided by my dissertation coordinator, Professor Vítor Hugo Ferreira, PhD, and was comprised of over 19,000 email addresses from all types of companies, and all over the country.

The questionnaire can be divided into two different segments. The portion that allows for the characterization of the different organizations, and the portion that will eventually lead to the creation of the preparedness index.

In the characterization segment there are questions that inquire upon multiple aspects of the responding organizations, like age, business segment, R&D annual investment, exportation, amongst others. These questions will help to better understand the Portuguese companies and

their interest and commitment to the Industry 4.0. With this data we were able to determine which company's characteristics are more likely to point if a company will opt for adopting the Industry 4.0. Characteristics like business area and annual R&D investment could be good analyzing points into this matter.

The "Preparedness Index", as mentioned previously, is comprise of three main dimensions, which have a number of questions within them. These questions will be scored in a five point Likert scale, which are scored as such:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

In this dissertation, companies that score a 5 (Strongly agree) are considered as being perfectly prepared for the implementation of the Industry 4.0, whilst the ones that score a 1 (Strongly disagree) are the exact opposite. This conclusion arose from the assumption that companies that feel as if every aspect of the Industry 4.0 is achievable and, won't cause to much turmoil in the organizational structure, will be the ones that are most likely well-informed and prepared to implement this new phenomenon.

The questions that were in the finalized version of the questionnaire, and their overall placement, are represented in the table below (Table 1). The questionnaire can be found in its entirety in the Annex I.

Main Propose	Main Dimensions	Questions	Scale
<p align="center">Industry 4.0 Preparedness Index</p>	<p align="center">Preparedness of the specific sector</p>	<ul style="list-style-type: none"> • Do you think that your particular industry will be able to take advantage of the Industry 4.0 technologies; • Are you of the opinion that the technology has reached a point in which the Industry 4.0 can actually be a reality; • Do you think that with the Industry 4.0 you'll be able to reduce on your company's expenses; • Is you company interested in adopting the inner workings of the Industry 4.0; • Are you of the opinion that cyber security has reached a point in which it can cope with the Industry 4.0 challenges; • Are you of the opinion that thanks to the Industry 4.0 your company will be able to better satisfy your clients; • Do you agree that with the Industry 4.0 companies will be able to reduce in their non-specialized workforce; • Do you thinks that with the adoption of the Industry 4.0 by companies that more work posts will be created; • Are you of the opinion that, in your company's case, if you were to adopt the Industry 4.0 you'd be able to attract new customers; • Do you think that other companies that directly interact with yours have standardized processes; 	<p align="center">Likert Scale (5 point scale) with 1 being "strongly disagree" and 5 "strongly agree"</p>

	<ul style="list-style-type: none"> • Are you of the opinion that your company would be benefited if your suppliers would utilize the Industry 4.0. 	
<p>Question's main purpose: The questions found above will determine the possible sectors that inspire the companies to make the change for the Industry 4.0 more. Specific factors to that sectors characteristics, like technology, workforce, operational expenses, client demands, supplier preferences and level of standardization, will be analyzed with one or two questions regarding each one of these topics. These are some of the characteristics that we found during the literature review that caused more concern in the perspective of the organizations (Kagermann, et al., 2013).</p>		
Preparedness of the host country	<ul style="list-style-type: none"> • Do you think that the success of implementing the Industry 4.0 is not correlated with the host country; • Are you of the opinion that the Portuguese government is incentivizing the companies to adopt the Industry 4.0; • Do you think that are enough qualified workers in Portugal to deal with the demands of the Industry 4.0; • Are you of the opinion that the Industry 4.0 will have a positive effect in the Portuguese economy. 	<p>Liker Scale (5 point scale) with 1 being "strongly disagree" and 5 "strongly agree"</p>
<p>Question's main purpose: The questions regarding the preparation of the host country will, in a way, weigh to which extent the efforts that the country's government is reassuring the companies of said country (Smit et al., 2016). We wanted to observe if the companies are of the opinion that the future plans of the country will provide stability, both by the commitment to these new technologies and the implementation of</p>		

	<p>curriculums that will sustain a future workforce of qualified workers (Hecklau et al., 2016).</p>	
	<p>Preparedness of the specific organization</p>	<ul style="list-style-type: none"> • Do you think that your current workforce would be able to deal with the demands of the Industry 4.0; • In your opinion do you think that industrial espionage will be decreased by the Industry 4.0; • Do you think that the Industry 4.0 will make the manufacturing process faster; • In your opinion do you think if your company were to adopt the Industry 4.0 that you would have to invest more funds into R&D; • Do you think that you would invest in the learning of Industry 4.0 expertise in the workforce that you currently have; • In your opinion do you think that the investment to convert your company into the necessary Industry 4.0 technologies would be gained in future revenue; • In your opinion are the processes of your company standardized.
<p>Question’s main purpose: Of the three dimensions this will be the one that will give us the most in-depth look into the specific situation of the company. The work force capabilities, monetary and intellectual investment, safety from industrial espionage and future benefits, are weighed in these questions, and will ultimately dictate to which extant is the level of preparation for the Industry 4.0 that the company has.</p>		

Table 1 - Questions of the online survey

The questions above came from the research made for the theoretical analysis of this dissertation. Subjects like the needs for employees with more technological backgrounds (Hecklau et al., 2016), the trust in the cyber security (Von Solms & Van Niekerk, 2013), the interaction that companies will have with each other in the context of the Industry 4.0 (Pfohl, et al., 2015) and the weight that the host country influence can have in the success (Buhr, 2015) plus some other subjects, are were found to be pivotal when analyzing the level of confidence that a company has with itself and its surroundings.

4.2.1 Questionnaire test phase

Before sending the finalized version of the questionnaire to this large sample of companies, first we performed a test phase that was comprised of five businesses, most of them from the moulds industry in Marinha Grande, given that these types of companies should be the ideal candidate to being interested in the Industry 4.0, as such, they would possess knowledge that would allow them to respond with the most reliable information, and being able to indicate if there was something incorrect with the data gathering process.

From the test phase of the questionnaire we were able to broaden the focus of some questions, for the gathering of more precise information, as well as, improving some of the wording of the questions.

4.3 Empirical analysis of the results

The data collected with the questionnaire was gathered between the 11th and the 30th of May, 2017. No major problem arose from this method of collection.

After the collection, the received data was transferred into an SPSS v. 22 (Statistical Package for the Social Sciences) file.

4.3.1 Characterization of the sample

The sample that was gathered is comprised of 149 Portuguese companies. Most of the responses were given by individuals that are high up in hierarchy (Table 2), meaning that the data that was gathered can be assumed as being the most accurate representation of the company possible.

	Frequency	Percent
CEO	16	10,7
CFO	5	3,4
Commercial Director	2	1,3
Commercial Manager	1	,7
Director of Operations	3	2,0
I.T.	1	,7
Industrial Director	1	,7
Management	30	20,1
Manager	69	46,3
Marketing Director	11	7,4
Quality Management	3	2,0
R&D Manager	3	2,0
Technical Director	4	2,7
Total	149	100,0

Table 2 - Position in the company of the respondent

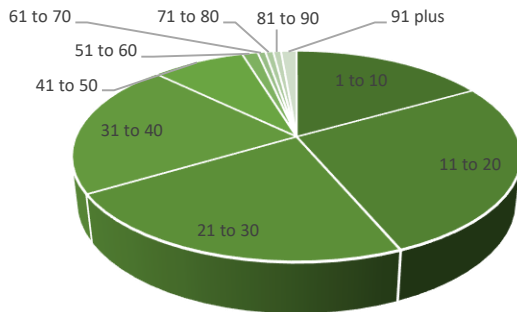


Figure 4 - Company's age by group

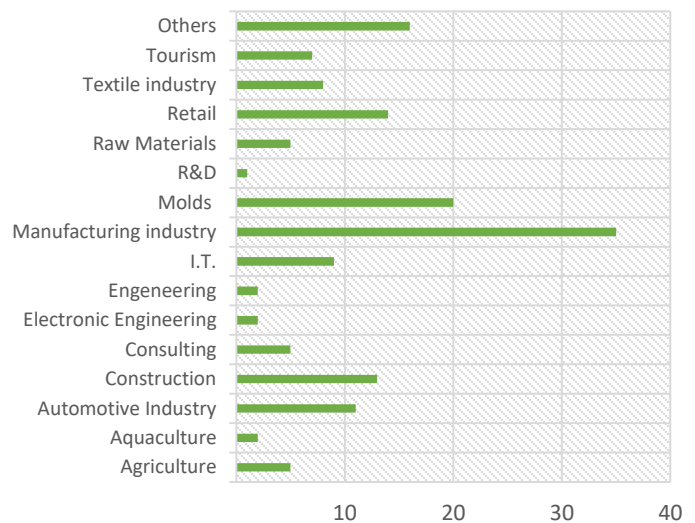


Figure 5 - Company's area of business

In figure 4 and 5 we can further observe the characteristics of the sample group gathered. Namely, we can analyze the age of the companies that submitted their responses in the figure 4, and see in which area do they conduct their business in figure 5.

From the figure 4, we can observe that our sample group is comprised from both, companies that are very recent and companies that have operated for a longer time. This gives the sample a diverse illustration of the Portuguese market. Although the sample is comprised of both older and younger companies, the largest amount of companies are positioned in the below 30 years segment (67% of companies).

In the figure 5 we get a sense of which sectors of activity the companies that participated in the questionnaire are a part of. The top two sectors of activity are the manufacturing industry and the moulds industry. These sectors are considered as being some of the prime sectors for the adoption of the Industry 4.0, given their high levels of machinery intervention and assembly line-like structure, as such, it is good that such a significant portion of my sample is comprised with them. Sectors of activity like tourism and consulting, are very unlikely to being able to take advantage of the Industry 4.0, but they are still companies and, as such their opinions on the future landscape of markets are still valid and welcomed. Once again, like the situation with the age of the companies, I was able to gather a very diverse sample group, which can prove to be an essential part of the analysis for the Industry 4.0 preparedness index. Just to mention that the portion named “Others” contains the collective data from companies that were solo, or had very few entries in their business areas, like insurance mediators, cleaning services, etc.

Portuguese Economic Sectors	
Agriculture, livestock, hunting, forestry and fishing	133 427
Extractive Industries	1 066
Manufacturing	66 729
Electricity, gas and water	2 471
Construction	77 906
Wholesale and retail trade	222 034
Transport and storage	21 638
Accommodation, catering and similar	91 826
Financial and insurance activities	18 324
Real estate activities	32 154
Education	54 626
Health activities and social support	86 978
Other Sectors	372 227
Total	1 181 406

Table 3 - Portuguese companies in thousands by economical sector
Source: <https://www.pordata.pt/DB/Portugal/Ambiente+de+Consulta/Tabela> (21st of September 2017)

In the table above (Table 3) we can observe the landscape of the Portuguese companies by sector of activity. This table will, in theory, allow for the comparison between the data sample that was gathered and the rest of the Portuguese companies. The data relative to the Portuguese companies appears to be similar to the data that we gathered, with two noteworthy exceptions, both manufacturing and the moulds industries have a larger representation in the data sample, with the latter not even having its own category in the data found in Pordata. The explanation for this discrepancy might be due to the fact that a large database of e-mails that was used in the inquiry phase was regarding companies in Marinha Grande, which are well-known for their deep links in the manufacturing and moulds industry. Apart from this distinction there is also the fact that we specified certain businesses that in the Portuguese data set fall into wider categories, like for example, manufacturing and automotive industry in the Pordata set all fall into the category of manufacturing. Despite these aspects being different in both sets, we still assume that the dataset that we collected can be assumed as being representative of the country's state, which will allow for the verification of the hypotheses to be reliable.

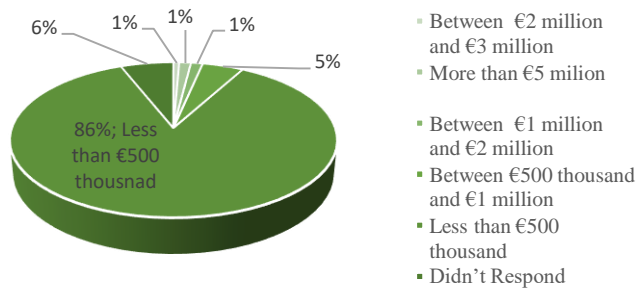


Figure 6 - Annual investment in R&D

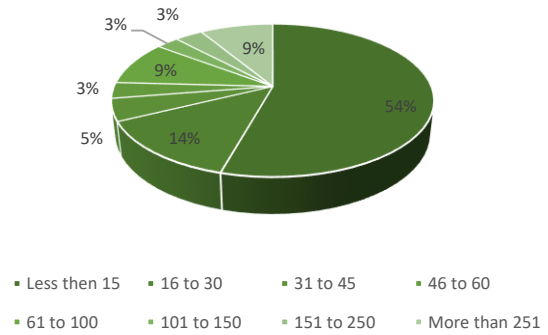


Figure 7 - Number of employees in the Company

Continuing the analysis of the sample, in the figure 7 it is comprised the data referring to the dimension, in terms of the workforce, of the companies inquired. And from the graph is apparent that the data sample appears to be composed from companies that have, in relative terms, a small amount of workers. This statement becomes clear when we see that the majority of the sample (more than 54%) has 15 or less active employees.

Figure 6 is a graphical representation of the sample's annual investments into their R&D departments. As it can be observed, the overwhelming majority of the sample (86%) is constituted by companies that invest at most €500 thousand. This raises two points, the first being that this seems to go with the rest of the data that has been analyzed so far, pointing that these aren't large conglomerates that can invest large sums of capital every year into R&D, but smaller younger companies that don't have the excess wealth available to further develop new products and services. The second refers to a possible mistake by my part, in hindsight I should have created more categories in-between the €0 annual investment and €500 thousand, since theirs such a high discrepancy between both. Never the less I think that the analysis can still be considered as substantial, giving the fact that it still encompass some companies that invest larger amount annually than €500 thousand.

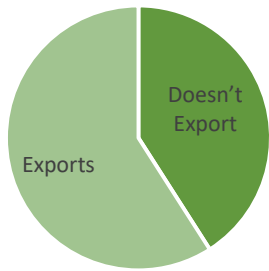


Figure 8 - Exportations

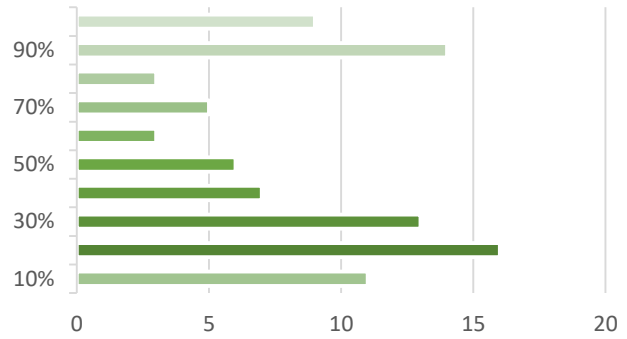


Figure 9 - Percentage of annual earnings obtained in exportations

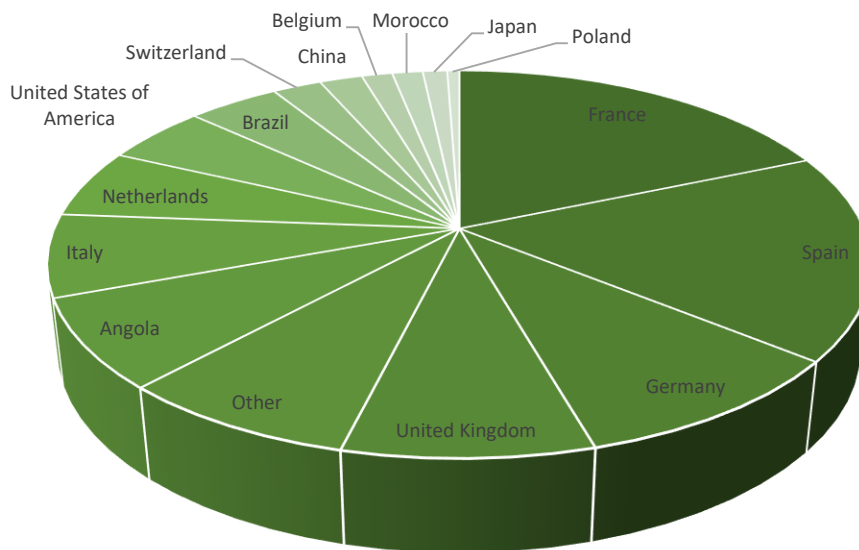


Figure 10 - Destination countries for the Portuguese exportations

In the next part of the survey, it was my objective to analyze the level of interaction that the Portuguese companies had with the outside world, mainly the amount, and characteristics of exportations that they conducted.

Figure 8 represents the percentage of the population that exports. In the graph it is shown that a larger percentage of the population (59%) have some kind of interaction by selling their goods to countries outside of their own. And in Figure 9 it is revealed, from the companies that export, just how much do exportations way in their annual earnings. The sample seems

to be rather equally divided, with companies making up between 10% and 100% of their annual earnings from other countries. What this means for the future analysis of the data, is that we have a good perspective from both companies that are highly influenced by the outside markets, as well as, companies that are influenced but in a smaller percentage, or in the case of the companies that don't export, the perspective of companies that only do business inside Portugal. This goes toward the analysis of the effects that standardization might have in the future of the markets, and companies that operate in supply chains with other international companies will need to be prepared to adopt some standardized characteristics in the future in order to facilitate the implantation of the Industry 4.0.

The data depicted in the Figure 10 represents, from all of the companies that export, which are the main markets that they tend to do business with. Unsurprisingly, most of countries that Portuguese companies tend to export to are in the European Union, like Italy, Germany or the United Kingdom. But there are still two countries that are more predominant within the European Union than the rest, and they are Spain and France. The most logical explanation to this occurrence might have to do with geographical convenience, since these two countries are some of the closest markets that are available to Portugal. Never the less, there are still a number of organizations that export to more distant markets, like the United States of America, Japan and China. If you take into account the research that was conducted by Roland Berger that characterized the countries into four different categories in which they would approach the Industry 4.0 (Roland Berger 2014), it seems that Portuguese companies perform direct business with all of the categories of countries. What does that imply to the standardization issues that might arise from countries within different “categories” of Industry 4.0 readiness, interacting with each other? Since that level of integration of the Industry 4.0 is still some years away from now, it is hard to tell, but based on the analysis of the Portuguese companies' expectancy for Industry 4.0 readiness we might see if those same companies see themselves as being in the category of “Hesitators”, or if they are in fact more confident of their situation. Just to finalize this analysis, in the group of countries categorized as “Others” there were countries like Argentina, Canada and countries from the United Arab Emirates, just to name a few.

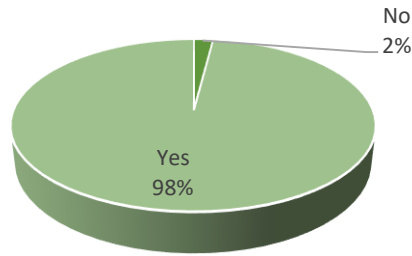


Figure 11 - If the companies consider that innovation is a necessity for good future results

Regarding the opinion that companies have towards innovation and its correlation with future success (Figure 11), almost all of the results (98%) were in favor that innovation is a constant aspect that needs to be further developed. The other responses (2%) seem to come from either outliers or companies that, in their specific situation, don't feel the obligation to improve on their product or service.

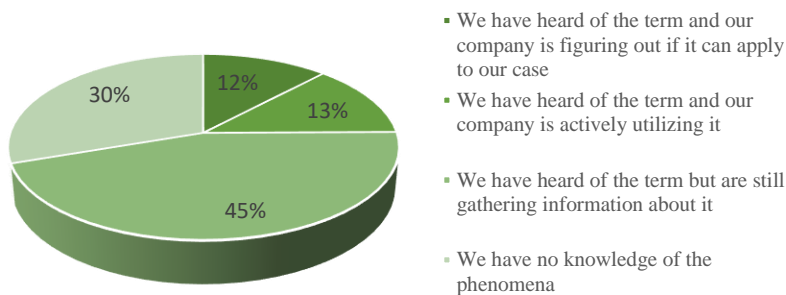


Figure 12 - What is the degree of knowledge and interaction that your company has with the Industry 4.0

In the Figure 12 we can observe the graphical representation of the sample's overall knowledge and level of commitment in regard to the Industry 4.0. Most of the organizations in the sample considered themselves as being aware of the Industry 4.0 (Figure 12), but they are still at a point in which they are gathering information about the phenomena (45%). Although be it only a passive knowledge about the Industry 4.0, it still shows that this new Industrial Revolution is one that is important enough to be investigated by multiple companies. Furthermore, in the whole sample 70% of the companies are aware of the

Industry 4.0. Of these 70%, 12% are in the process or have already adopted themselves the procedures and technologies to make their business apt for the Industry 4.0, whilst 13% of the sample are still gathering data to see if the change would be something beneficial to them. Given the short life that the Industry 4.0 has had until now, and the few companies that have adopted it fully, it seems normal that some firms don't feel confident enough to make the investments required to upgrade their functionalities.

4.3.2 Validity and reliability of the data for the Index

To validate our data sample, in order to assume that the conclusions that we will taking from the analysis of the index are significant to the whole Portuguese landscape, it is necessary to do some statistical tests. For these tests I used a five point Likert scale. The questions were all built with the caution that they were following the same direction, with a 1 representing the same statistical value all throughout the 22 questions.

The size of the sample group will be smaller for the consideration of the Preparedness Index, this because some companies didn't respond to all, or at least to one, of the questions that comprises the three main variables (A, B and C). As such starting from now we will be analyzing a sample group comprised of 109 responses for the variable "Preparedness of the specific sector", 113 responses for the variable "Preparedness of the host country" and 111 responses for the variable "Preparedness of the specific organization".

The first test I will be conducting will have the objective of analyzing the Skewness of my sample. To get the results that are represented in the table below (Table 3), I used the three variables (A, B and C) that encompass the combined 22 questions. These three new variables were formed with the mean values of each of the groups of questions for each company's response.

Statistics				
		A	B	C
N	Valid	109	113	111
	Missing	40	36	38
Skewness		-,576	-,258	-,791
Std. Error of Skewness		,231	,227	,229

Table 4 - Skewness of the data sample

As we can see, in the table above (Table 4), the values of the Skewness of our data sample appear to be negative meaning that our data is negatively skewed. Both variable A and C are skewed at a moderate level (between -1 and $-0,5$) with the variable B being considered as approximately asymmetric (between 0 and $-0,5$) (George & Mallery, 2010). This will most likely mean that a larger portion of the responses will be above the half-way point (3) in the Likert scale, but with the responses for the preparedness of the host country (B) being the closest to the half-way point (3).

With the knowledge that the data has a negative skewed value, it is normal to assume that the data gathered won't have a normal distribution. This can also be confirmed with the knowledge that most data collected with Likert scales tend to not have normal distributions either (Muthén & Kaplan, 1985). Never the less, I conducted both Kolmogorov-Smirnov test and the Shapiro-Wilk tests for normality (Table 5), with both identifying the sample as not normal ($p\text{-value} < \alpha=0.05$). As such we will have to utilize tests that don't assume normality (non-parametric tests) to confirm the validity of our data for the index (Pallant, J. 2013).

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
A	,116	106	,001	,970	106	,017
B	,116	106	,001	,812	106	,014
C	,117	106	,001	,789	106	,001

a. Lilliefors Significance Correction

Table 5 - Test of Normality (Kolmogorov-Smirnov & Shapiro-Wilk)

Next we analyzed the Cronbach's Alpha test (Cronbach, L. J. 1951). This test will allow to confirm the reliability of a scale, in this particular case a five point Likert scale. We implemented the Cronbach's Alpha test into the combined three sets, each one with n number of subsetting responses (Table 6).

Reliability Statistics	
Cronbach's Alpha	N of Items
,738	3

Table 6 - Cronbach's Alpha test (Assuming three main variables)

In the Cronbach's Alpha test, values closest to 1 are considered ideal. In the sample's specific case the Alpha is 0,738, which amounts to a good value (Tavakol & Dennick, 2011), consolidating the fact that the reliability of the analysis is high and, further helping assuming the findings regarding the preparedness index.

In this analysis we also confirmed that the items are measuring the same underlying characteristics, this because in the Inter-Item Correlation Matrix (Table 16 in Annex II), as well as, in the Correlated Item – Total Correlation column, in the Item Total Statistics (Table 17 in Annex II), there aren't any negative values. Plus the values of the Inter-Item Correlation Matrix fit the ideal values of between 0,2 and 0,4 (Briggs & Cheek, 1986), except for one of the correlations (0,654).

Lastly, we observed the correlation values of the variables gathered (Table 7). The correlation test serves as a way to identify the strength and direction of the connection between two variables at a time. The ideal values to get from this analysis are the ones closest to either -1 or 1 (Kendall, 1948), since these values point to the variables being connected.

Correlations					
			A	B	C
Spearman's rho	A	Correlation Coefficient	1,000	,469**	,626**
		Sig. (2-tailed)	.	,000	,000
		N	109	108	106
	B	Correlation Coefficient	,469**	1,000	,408**
		Sig. (2-tailed)	,000	.	,000
		N	144	149	148
	C	Correlation Coefficient	,626**	,408**	1,000
		Sig. (2-tailed)	,000	,000	.
		N	143	148	148

** . Correlation is significant at the 0.01 level (2-tailed).

Table 7 - Correlation test

In this particular case, we conducted this test utilizing the Spearman rho approach, since the data is classified as non-parametric and this is the test that better deals with those kinds of characteristics. As we can see from the table above (Table 7), the correlation levels are all positive, meaning that when a company scores a variable with a high score the other variables will most likely have a high score as well. In regards to the strength of the relationship between the variables, the values seem to either be considered as having a medium ($r=0,3$ to $0,49$) or large ($r=0,5$ to $1,0$) correlation (Cohen, 1988).

5. Results

The creation of the preparedness index came to existence from the direct answers that were gathered in the online survey. From each of the three main dimensions, represented bellow as A, B and C (Preparedness of the specific sector, Preparedness of the host country and Preparedness of the host country, respectively), we use their mean values in order to observe what is the overall felling of the companies towards that respective dimension.

With the “Preparedness Index” built and the data from the Portuguese companies gathered we can now start to either confirm or deny the four hypotheses that we previously proposed.

- **H1:** The Portuguese companies will score above the average (>50%) in the preparedness index;

This first hypothesis will serve to understand if in fact the Portuguese companies are, or aren't, prepared enough to be able to take the fullest advantage of the Industry 4.0. Assuming that values below 50% (3 in the Likert scale) are indicative that the companies either have doubt in the overall likely wood that the Industry 4.0 will have success, that the host country has the tools to help these companies or that their specific business area will benefit from the changes, values above 50% will in theory, indicate that the companies have good hopes for the future of the Industry 4.0 in Portugal.

		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	109	113	111
	Missing	40	36	1
Mean		3,4295	3,4381	3,5367
Percentage (out of 100%)		57,158%	57,302%	58,945%
Preparedness Index for the Portuguese companies		57,802%		

Table 8 - Test for Hypothesis 1

The first hypothesis (H1) appears to have been confirmed (Table 8). The Portuguese companies in our dataset scored above a 50% in the preparedness index (57,802%). It is also important to note that the variable that contributed with the highest value towards the overall final score of the index, was the “Preparedness of the specific organization” (C). This only comes to show that the companies that responded to the survey believe in their capabilities enough, that even a change to the Industry 4.0, and all the perceivable difficulties that would arise from that change, don’t differ them from thinking that they wouldn’t be able to thrive in this new ecosystem.

It is also noteworthy to observe that the variable “Preparedness of the host country” (B), came in second. This only comes to show that the Portuguese companies are confident in their country, this because as we saw previously, Portugal appears to be aware of the future benefits that an early adoption of the Industry 4.0 could have to the economy, as such, they are actively making plans to help smaller companies upgrading their infrastructure, creating syllabi for the demands of the future workforce, and creating programs to the development of new technologies, amongst other initiatives. This might be enough of a motivation for companies to be confident in their country, and want to make the leap into the Industry 4.0.

The variable that appears to have the companies most worried is “Preparedness of the specific sector” (A). This variable might start to grow in confidence when more companies start to adopt the Industry 4.0, because as it stands now, there aren’t many other early adopters to make the companies confident enough. Despite the fact that this is the variable with the least amount of confidence, the value is still above the 50% mark, meaning that companies do still have confidence in their surroundings.

Despite this hypothesis being confirmed we still don’t have enough statistical evidence to make the conclusion that these results will be observed for the rest of the Portuguese companies. As such, we are going to conduct a one-sample Binomial test that will allow us that assumption (Pallant, 2013). For this test I created a new variable by the name of Index, represented by the letter I , which is the mean value of the three main variables (A, B and C).

$$H_0: P_I = 0.6 \text{ vs } H_1: P_I \neq 0.6 \text{ with } \hat{P}_I = 0.67$$

Index	
Grand Total	
N	106
> 3	80,2%
< 3	13,2%

Figure 13 - Percentage of companies that score a 3 in the Index

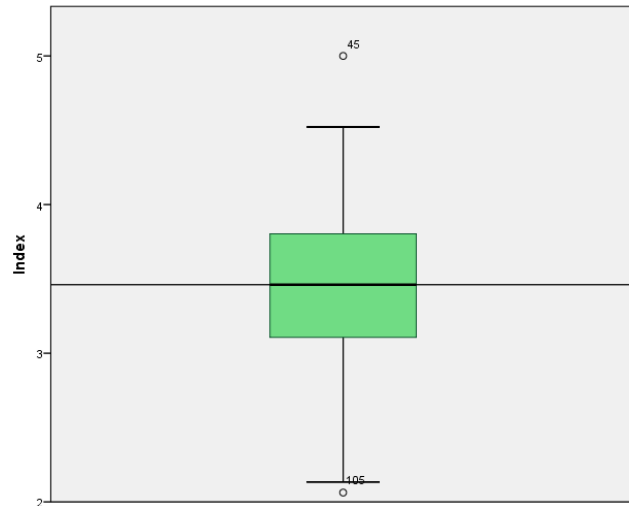


Figure 14 - Boxplot for the Preparedness Index (Considering n=106)

The mean of the responses given by the companies was above 3 with, as we can see in the image above (Image 14), the number of companies responding 3 being close to 67% (80,2%-13,2%) (Image 13). As such, the test that we will be conducting will inquire if the more than 60% of Portuguese companies will also be in the same position as the companies in our data sample.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by Index	One-Sample Binomial Test	,339	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Figure 15 - One-sample Binomial test for the Preparedness Index

The value that was obtained from the binomial test gave a significance value of 0,339 (Image 15), which will lead us to not reject the null hypothesis ($p\text{-value} = 0,339 > \alpha = 0,05$), meaning that we don't have enough statistical evidence to prove that 60% of the Portuguese companies will score the Preparedness Index below a score of 3, which is the half-way measure of our Likert scale.

- **H2:** Companies that conduct business with other countries (exportations) will score higher values in the preparedness index;

As we previously saw, the split in this dataset of companies that export, and companies that don't, is very close (59% and 41% respectively), and so, the observation of which of the two groups would be more prepared to deal with the Industry 4.0, might be pivotal into predicting which companies would be more willing to apply the new technologies and processes to their already existing business models. To gain access to the data I divided the database into two groups, the first, for companies that export, and the second, for companies that don't export.

		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	68	68	66
	Missing	20	20	22
Mean		3,4733	3,4191	3,5974
Percentage (out of 100%)		57,888%	56,985%	59,957%
Preparedness Index for the Portuguese companies that Export		58,277%		
		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	41	45	45
	Missing	20	16	16
Mean		3,3570	3,4667	3,4476
Percentage (out of 100%)		55,950%	57,778%	57,460%
Preparedness Index for the Portuguese companies that do not Export		57,063%		

Table 9 - Test for Hypothesis 2

The second hypothesis has been proven, with the aid of the table above (Table 9). In the first half of the table (Preparedness Index for the Portuguese companies that Export) the value that was achieved by the companies that export amounted to 58,277% in the preparedness index, whilst the second half of the table (Preparedness Index for the Portuguese companies

that do not Export), which represented the part of the population that doesn't export, only achieved 57,063% in the preparedness index. As such, companies that export will in fact have score higher in the index when compared to their counter parts.

With this hypothesis confirmed we can speculate that, since the goal of the Industry 4.0 is to create a network in which all the parts of the supply chain are connected to each other via various technological components, and that those parts of the supply chain tend to be spread throughout various countries, the fact that the companies that export, to a certain degree see their earnings directly affected by outside sources, will probably mean that they would be more concern in making their business as prepared as possible to accommodate the future of their sales. As such, these are the companies that will be more informed and prepared to adopt the Industry 4.0, just that they don't see any drops in their revenue stream.

It is still fair to point that, although the companies that export have a higher preparedness index value (58,277%), the companies that don't export also have a positive value (57,063%), meaning that even though their revenue stream isn't directly linked to sales to other countries, these companies must be aware that is very rare that the totality of a supply chain is confined to one country, meaning that some part of their company is going to effected by the outside sources, like from suppliers, for example, as such, a positive value in this remark shows that this portion of the population can still be a source of ease when thinking of the future of the country.

Unfortunately due to the fact that we split the data sample, we won't be able to perform the One-way binomial test that was conducted in the first hypothesis with the objective of approaching the findings to the whole Portuguese organizational landscape. This happens due to the fact that a certain number of company's responses (n) are needed to assume that the conclusions are representative. Furthermore, for the next two hypotheses (H3 and H4), since the number of responses are divided again, this test won't be possible to use either. Despite this, we are still going to assume that the conclusions drawn by the hypothesis are significant to the rest of the country, mainly due to the fact that this was proven in the first hypothesis, meaning that the possible of the results being replicated is high.

- **H3:** Companies that have a higher knowledge in the Industry 4.0 will have higher results in the preparedness index;

This third hypothesis will hopefully demonstrate, if proven valid, that the Industry 4.0 is a phenomena that could be highly beneficial to a vast number of companies, but with every revolutionary idea there are misconceptions that form in the minds of the population.

		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	18	19	19
	Missing	1	0	0
Mean		3,9747	3,7763	3,9023
Percentage (out of 100%)		66,245%	62,938%	65,038%
Preparedness Index for the Portuguese companies that consider their knowledge of the Industry 4.0 as being “We have heard of the term and our company is actively utilizing it”		64,741%		
		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	17	17	17
	Missing	1	1	1
Mean		3,6310	3,3676	3,7647
Percentage (out of 100%)		60,517%	56,127%	62,745%
Preparedness Index for the Portuguese companies that consider their knowledge of the Industry 4.0 as being “We have heard of the term and our company is figuring out if it can apply to our case”		59,796%		
		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	58	62	60
	Missing	9	5	7
Mean		3,2304	3,3427	3,3929
Percentage (out of 100%)		53,840%	55,712%	56,548%
Preparedness Index for the Portuguese companies that consider their knowledge of the Industry 4.0 as being		55,367%		

“We have heard of the term but are still gathering information about it”				
		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	16	15	15
	Missing	29	30	30
Mean		2,6580	2,7844	2,8120
Percentage (out of 100%)		44,300%	46,407%	46,867%
Preparedness Index for the Portuguese companies that consider their knowledge of the Industry 4.0 as being “We have no knowledge of the phenomena”		45,858%		

Table 10 - Test for Hypothesis 3

To test this hypothesis we divided the sample into four different sections, each of these sections comprised by a different level of knowledge towards the Industry 4.0. The ranking of knowledge goes from lowest to highest, as follows, as well as, the percentage of the sample that they represent:

- We have no knowledge of the phenomena (12,90%);
- We have heard of the term but are still gathering information about it (12,15%);
- We have heard of the term and our company is figuring out if it can apply to our case (44,65%);
- We have heard of the term and our company is actively utilizing it (30,20%).

With these notions and the table above (Table 10) we can prove the validity of the third hypothesis. In fact, the highest the knowledge and involvement a company has towards the Industry 4.0, the higher the value they will score in the preparedness index (77,69% > 59,796% > 55,367% > 45,858%).

The companies that found there in the knowledge in the Industry 4.0 as being “We have heard of the term and our company is actively utilizing it”, in other words the highest value in this

particular scale, obtained a 64,741% in the index. This value is to be expected, since these companies are already in utilizing the Industry 4.0 to a certain degree. In terms of the totality of the sample, the amount of companies that selected this knowledge level, isn't very big, around 13% (19 companies). This only comes to show that early adoption of any new manufacturing trend is risky, and companies are aware of this fact.

With a preparedness index value of 59,796%, the second highest score, will be attributed to the companies that selected "We have heard of the term and our company is figuring out if it can apply to our case" as their knowledge level. In this level companies have a very good understanding of the phenomena, but for some reason, haven't yet adopted the Industry 4.0. This knowledge level was associated with the same amount of companies has the previous, and highest level, meaning that the percentage of companies that is thinking of adopting the Industry 4.0 is the same as the ones that have. And so, in the near future, if in fact the Industry 4.0 proves to be a good investment, we can see the number of companies adopting the Industry 4.0 more than double, with a lot of other companies following the trend.

The third highest value (55,367%) will be awarded to the companies that selected "We have heard of the term but are still gathering information about it" as their knowledge. This will encompass the vast majority of the votes (67 companies), and just goes to show that a vast percentage of Portuguese companies have heard of the Industry 4.0, but not to a point in which they can be certain of its future success.

The last knowledge level "We have no knowledge of the phenomena" obtained a value of 45,858%, which is to be expected of companies that have no idea of the phenomena. But the most interesting thing to note about this knowledge level comes from the number of companies that selected it. A big percentage of the sample all fell into this category (30%), which would point that Portugal still has a big number of companies that is uninformed. As a recommendation, I would like to suggest that the Portuguese government to create some awareness to the Industry 4.0 and its characteristics. This hypothesis just comes to show that the more a company knows about the Industry 4.0, the more they'll see that the risks aren't as big as they originally thought, and this might even lead to some companies, that otherwise wouldn't even think of the option of a smart factory, they themselves adopt the Industry 4.0.

- **H4:** Companies that operate in business areas that are more likely to be early adopters of the Industry 4.0 (manufacturing, molds, etc.) will have higher results in the preparedness index.

The final hypothesis (H4) will once again divide the sample into two groups, in one part the companies that operate in areas that more benefit from the introduction of the Industry 4.0, and the companies that don't. I've identified the companies that are better suited for the Industry 4.0 as the companies that have assembly lines and work with raw materials, as such, in this data sample, these will be the moulds companies, manufacturing companies and companies that deal with raw materials. This selection of companies, came from the literature review made previously, that suggested that these types of companies can take further advantage of the technology and processes, at least at first, better than the others (Lee, et al., 2015; Brettel, et al., 2014).

		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	43	44	42
	Missing	10	9	11
Mean		3,5983	3,5455	3,6871
Percentage (out of 100%)		59,972%	59,092%	61,452%
Preparedness Index for the Portuguese companies that are in business areas more likely to be early adopters of the Industry 4.0		60,172%		
		A (Preparedness of the specific sector)	B (Preparedness of the host country)	C (Preparedness of the specific organization)
N	Valid	66	69	69
	Missing	30	27	27
Mean		3,3196	3,3696	3,4451
Percentage (out of 100%)		55,327%	56,160%	57,418%
Preparedness Index for the Portuguese companies that are in business areas less likely to be early adopters of the Industry 4.0		56,302%		

Table 11 - Test for Hypothesis 4

In the table above (Table 11) we can see that our fourth hypothesis has been confirmed, meaning that the companies that are positioned in certain areas more likely to take first advance of the Industry 4.0 are the ones that have a higher preparedness index (60,172% > 56,302%).

It is also of interest to note that the highest number of companies (69) seems to be of business areas, that I assume won't be in the early adopters of the Industry 4.0, which obtained a score of 56,302%. On the other hand the rest of the companies (44) obtained a positive value of 60,172%. Although the number of companies that have a higher likelihood of adopting the Industry 4.0 is smaller than the other option, these companies still amount to almost 36% of the total sample. This is still, with all things considerate, a very high percentage, that might be explained by the fact that one of the mailing data bases being from companies within Marinha Grande, a zone in Portugal that has a very high number of companies in the manufacturing and mould industries. But what this also means, is that our data sample shows the reality of both companies that are interested and, those that might not be, in the Industry 4.0.

With all of the hypotheses analyzed we arrive to the final table (Table 12) that shows the ones that were verified and the ones that weren't.

Hypotheses	Verified
H1: The Portuguese companies will score above the average (>50%) in regards to the preparedness index	Yes
H2: Companies that conduct business with other countries (exportations) will score higher values in the preparedness index	Yes
H3: Companies that have a higher knowledge in the Industry 4.0 will have higher results in the preparedness index	Yes
H4: Companies that operate in business areas that are more likely to be early adopters of the Industry 4.0 (manufacturing, molds, etc.) will have higher results in the preparedness index	Yes

Table 12 - Summary of the verification of the Hypotheses

6. Conclusion

In this section of the dissertation we will summarize the key findings of this study, analyzing what the conclusions that were obtained from the various hypotheses. We will also be mentioning some contributions that this paper might have to the literature. Lastly we will be referring some limitations and recommendations for further research.

6.1 Main conclusions of the study

As we previously saw and discussed, Portugal as a country has never actually been able to take full measures into exploring any of the three previous Industrial Revolutions. Matters like geographical position, limited resources or not being to create technologies superior to the other countries, meant that Portugal could never stand to be in the front competing directly, but rather sitting in the sidelines, only getting a portion of the profits that the countries that were directly evolved got. But with the fourth Industrial Revolution, Portugal has got another chance to be a part of the frontrunners, and get as many benefits as other countries. The characteristics of the Industry 4.0 are such that, criteria like geographical position and natural resources aren't as important as in the other Industrial Revolutions, and so, all that is needed now is early investment, from the companies, the industries and the host countries, and for the existence of confident that the "smart factories" can bring the results that they promise.

In this dissertation the concept of innovation was mentioned and analyzed, with the two main types of innovation being explored (incremental and radical) (Abernathy & Utterback, 1978). And so, now that we have a complete grasp of the Industry 4.0, the objective was to try and categorize in which of the two groups, this phenomena would fit better. This task prove itself as being rater hard to accomplish, mainly due to the fact that the Industry 4.0 has characteristics that exist within both. For example, the Industry 4.0 will improve upon certain aspects of factories, making them smart factories, but these improvements aren't altogether

innovative (incremental), with some of them being already utilized in factories previous to this phenomena, but on the other hand, the effects that this fourth Industrial Revolution will have in the companies, the sectors and the countries is closer classified as something from a radical innovation point-of-view. This will lead to the conclusion that Abernathy, W. J., and Clark, K. B also reached in 1985, that there are multiple types of innovations that can occur depending on specific characteristics, and in our case, generalizing isn't doing the Industry 4.0 any justice.

Despite this realization, Industry 4.0 is still an innovation and, as such, it also falls into the same problems and benefits that other innovations go through. These are some of the points in which companies must focus their efforts, if they hope that the implementation of Industry 4.0 could go smoothly. Peter Drucker (1998) point out that when problems arise from these types of situations, the cause can be oftentimes pinpointed to a lack of good management of the workforce and other resources. This is a good aspect that managers need to take into account if they want to improve their current way of conducting business, the way that a smart factory operates is very distinct to a regular factory, as such, a well thought out plan needs to be established to minimize possible problems.

The size of the company was previously discussed as a factor that may influence the success in Industry 4.0 implementation. This because previously, success in such a significant investment was such that only companies with a large amount of capital available were able to achieve it. With the Industry 4.0 the same isn't necessarily the norm, obviously there are still the large conglomerates like Siemens that are paving the way, but small and medium enterprises are also a big driving force that are interested in the fourth Industrial Revolution. The problems that usually halts these smaller companies from improving in these manners can be summarized by monetary troubles and the process of changing the company's culture. Countries are trying to solve the first problem by creating funds that would allow the acquisition of the technology, as well as, some of these smaller companies being directly linked by partnerships with large organizations (Imaginatik & Masschalenge, 2016) that might help the transmission. But for the problems that arise from the modification of the company's culture, there isn't a safe way to approach this subject, but just like in the case of the innovation prevailing, a good management is highly required to guarantee success.

During this dissertation it was observed that for Industry 4.0 to bring successful returns to a company there are a lot of prerequisites that need to be met. The implementation of all the technological components (CPS, IoT, Big Data, etc.) not only by the company itself (Angelov, 2013), but by the different partners in the supply chain (Pfohl, et al., 2015). These changes aren't either cheap or easy on the structure of the business, plus there isn't any guarantee that they will work for every single company. And yet, why is there such a big interest by the business world in this phenomenon? The answer might come from the promises made by these changes. Waste reduction (Geissbauer, et al., 2016), increase in productivity (Hermann, Pentek & Otto, 2016), higher levels of customization (Brettel, et al., 2014), just to name a few. These are some of the causes from which Germany is expecting to earn an extra €78 billion by 2025 (Bauer & Horváth, 2015).

The level of confidence that a company has to have towards a matter as significant as a new Industrial Revolution, that has the possibility of changing the way whole company deals with their business, has to be very high. Matters like changing the company's inner workings, if not done correctly could have effects as severe as the termination of said company. But, in the other hand, companies that don't keep up with the times and refused to innovate, also tend to not work out and lead to closure. As such, a company needs to have a very clear vision of their future, and in the case of the Industry 4.0, have a clear notion of the phenomena a good manager (Drucker, 1998), as well as, a solid idea of the likelihood of success. Unfortunately for most, the Industry 4.0 is still a very new concept, as such, there aren't many companies that have adopted it, causing the other companies to not have a clear understanding of the success rates.

This weighing of the benefits and drawbacks of implementing the Industry 4.0 is something that we tried to analyze with our questionnaire. Companies that are aware of their position regarding adoption and the possible earnings and problems that can arise, will tend to score higher in the Likert scale. Meaning that the closer a company score to a 5 the more likely that said company is prepared to face the problems.

Portugal appears to have companies that are prepared and willing to adopt Industry 4.0 (H1). Furthermore, these companies all seem to have some characteristics that point to them being the ideal first candidates for the integration of the Industry 4.0 (H2, H3 and H4). This fact

might be a helping point to the Portuguese government to focus, at least in an early state, in the companies with these sort of characteristics, and further down the line try to help all sorts of companies. This is an important point to highlight, since most of companies will only be convinced that Industry 4.0 is a worthwhile investment when they see other companies achieving those success, and the most likely companies to gain success from the Industry 4.0 are the companies that are well informed, have a direct connection with partners outside of their host country and operate in sectors that are highly reliant on in production lines.

Portugal and, in particular the companies within the country, have the possibility of being able to take advantage of the Industry 4.0, since they seem to be knowledgeable about their current position, as well as, what they need to accomplish in order to make this phenomenon expand in the future. This is backed up with the values of the preparedness index that was gathered from the Portuguese companies. And with this, we finally have enough support to answer the main question - "Is Portugal prepared for the future?" Yes, we would say so.

6.2 Contributions for the literature

This study brought forth a concept that is yet to be explored in the literature (Industry 4.0 and its intricacies, which was the amount of confidence and preparedness that the companies themselves perceive to exist). We feel like this is a very important analysis, since ultimately the decision to advance and try something as revolutionary as the Industry 4.0, needs to come from within the company. Sometimes the outside world might see the decision to innovate, as being obvious, but more often than not, the organizations might have some concerns that make them uneasy. This concept is why we feel that the organizations themselves are the best telltale indicator of the acceptance and whininess to improve.

6.3 Limitations and Recommendations for Further Research

In terms of limitations regarding this investigation, the size of the sample collected and its randomness/representability might be the most evident shortcoming. A bigger data sample would mean more certainty regarding the study's assumptions. Adding to the limitations is the fact that we only analyzed one country's case. Having at least one more country would give context to some indicators and conclusions.

As for further research, and exploring one of the limitations that was previously mentioned, applying the index to other countries, especially if those countries have extremely different characteristics, can be enlightening into understanding what characteristics have higher influence in the point of view of the country, in aiding the companies to adopt the Industry 4.0. Analyzing other countries that have a higher percentage of companies in different industries may also be a good reference point into seeing which market segments are more likely to be improving their operations into smart factories. The differences in managerial styles (Hofstede, G. 1993) can also have a high effect in the acceptance of the phenomena, as such, analyzing such differences is also a good way to explore the probability of Industry 4.0 integration having traction in different regions of the world.

Researching the long-term changes that the Industry 4.0 might have in a country's manufacturing culture and overall economic state can show the way that the world could be changing in the future, and help the governments and companies getting there as fast as possible.

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Annex

Annex I – Questionnaire

The question that have a red asterisk (*) are of mandatory response.

First page – Characterization of the company

1. What position do you have in your organization?
2. Your company's age? *
3. Number of employees? *
4. In which sector/sectors does your company participate? *

(You can chose multiple options)

Agriculture;

Food Industry;

Audiovisual and media;

Biotechnology;

Communications;

Construction Industry; Medical Devices;

Electronic Engineering;

Mechanical Engineering;

Mining, metals and minerals;

Automotive industry;

Footwear industry;

Pharmaceutical industry;

Manufacturing industry;

I.T.;

Maritime industries;

Raw materials;

Furniture;

Molds;

Financial services;

Retail services;

Textiles & Clothing;

Transportation;

Tourism.

(With the option to insert any other choice)

5. Annual investment to the Research and Development department

- Less than €500 thousand;
- Between €500 thousand and €1 million;
- Between €1 million and €2 million;
- Between €2 million and €3 million;
- Between €3 million and €4 million;
- Between €4 million and €5 million;
- More than €5 million.

6. Does your company exports to other countries? *

- Yes
- No

Second page – Exportations

(Only the companies that responded “yes” to the question number 6 of the first page got to respond to the questions of the second page. The ones that responded “no” were automatically sent to the third page.)

1. To which countries does your company export to? *

(You can chose multiple options)

- Germany
- Angola
- Brazil
- China
- Spain
- United States of America
- France
- Netherlands
- Italy
- Japan
- United Kingdom

(With the option to insert any other choice)

2. Percentage of the annual revenue that comes from exportations *

(Scale from 0% to 100%)

Third Page - Preparedness of the specific sector

1. Do you think that innovation is a necessity for your company remaining successful?*

Yes

No

2. What degree of knowledge and interaction does your company have with Industry 4.0? *

We have heard of the term and our company is figuring out if it can apply to our case;

We have heard of the term and our company is actively utilizing it;

We have heard of the term but are still gathering information about it;

We have no knowledge of the phenomena.

3. Preparedness of the specific sector (1 = Strongly Disagree; 5 = Strongly Agree) *

- Do you think that your particular industry will be able to take advantage of the Industry 4.0 technologies;
- Are you of the opinion that the technology has reached a point in which the Industry 4.0 can actually be a reality;
- Do you think that with the Industry 4.0 you'll be able to reduce on your company's expenses;
- Is your company interested in adopting the inner workings of the Industry 4.0;
- Are you of the opinion that cyber security has reached a point in which it can cope with the Industry 4.0 challenges;
- Are you of the opinion that thanks to the Industry 4.0 your company will be able to better satisfy your clients;
- Do you agree that with the Industry 4.0 companies will be able to reduce in their non-specialized workforce;
- Do you think that with the adoption of the Industry 4.0 by companies that more work posts will be created;
- Are you of the opinion that, in your company's case, if you were to adopt the Industry 4.0 you'd be able to attract new customers;
- Do you think that other companies that directly interact with yours have standardized processes;
- Are you of the opinion that your company would be benefited if your suppliers would utilize the Industry 4.0.

Fourth Page - Preparedness of the host country

1. Preparedness of the host country (1 = Strongly Disagree; 5 = Strongly Agree) *
 - Do you think that the success of implementing the Industry 4.0 is not correlated with the host country;
 - Are you of the opinion that the Portuguese government is incentivizing the companies to adopt the Industry 4.0;
 - Do you think that are enough qualified workers in Portugal to deal with the demands of the Industry 4.0;
 - Are you of the opinion that the Industry 4.0 will have a positive effect in the Portuguese economy.

Fifth Page - Preparedness of the specific organization

1. Preparedness of the specific organization (1 = Strongly Disagree; 5 = Strongly Agree)*
 - Do you think that your current workforce would be able to deal with the demands of the Industry 4.0;
 - In your opinion do you think that industrial espionage will be decreased by the Industry 4.0;
 - Do you think that the Industry 4.0 will make the manufacturing process faster;
 - In your opinion do you think if your company were to adopt the Industry 4.0 that you would have to invest more funds into R&D;
 - Do you think that you would invest in the learning of Industry 4.0 expertise in the workforce that you currently have;
 - In your opinion do you think that the investment to convert your company into the necessary Industry 4.0 technologies would be gained in future revenue;
 - In your opinion are the processes of your company standardized.

Annex II – Data obtained from SPSS

Reliability Test: Considering the 3 main variables

		N	%
Cases	Valid	106	71,1
	Excluded ^a	43	28,9
	Total	149	100,0

Table 13 – Processing Summary of the sample for the Preparedness Index

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,738	,739	3

Table 14 - Cronbach's Alpha test (Assuming combined 3 variables)

	Mean	Std. Deviation	N
A	3,4271	,65461	106
B	3,4292	,66526	106
C	3,5270	,64020	106

Table 15 - Statistics regarding the 3 variables

	A	B	C
A	1,000	,426	,654
B	,426	1,000	,377
C	,654	,377	1,000

Table 16 - Correlation Matrix for the 3 variables

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
A	5,1756	10,067	,942	,888	,955
B	5,2005	10,040	,931	,866	,963
C	5,1473	9,671	,942	,889	,955

Table 17 - Cronbach's Alpha test for each of the 3 variables

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
7,7617	22,018	4,69237	3

Table 18 - Standard Deviation test for the 3 variables

Hypothesis 2

- Statistical analysis assuming only companies that export (H2)

Statistics

		A	B	C
N	Valid	68	68	66
	Missing	20	20	22
Mean		3,4733	3,4191	3,5974

Table 19 - Mean values for the companies that export (H2)

- Statistical analysis assuming only companies that don't export (H2)

Statistics

		A	B	C
N	Valid	41	45	45
	Missing	20	16	16
Mean		3,3570	3,4667	3,4476

Table 20 - Mean values for the companies that do not export (H2)

Hypothesis 3

- Statistical analysis assuming only companies that selected “We have heard of the term and our company is actively utilizing it” as being their knowledge of the Industry 4.0 (H3);

		A	B	C
N	Valid	18	19	19
	Missing	1	0	0
Mean		3,9747	3,7763	3,9023

Table 21 - Mean values for the companies that fit the criteria (H3)

- Statistical analysis assuming only companies that selected “We have heard of the term and our company is figuring out if it can apply to our case” as being their knowledge of the Industry 4.0 (H3);

		A	B	C
N	Valid	17	17	17
	Missing	1	1	1
Mean		3,6310	3,3676	3,7647

Table 22 - Mean values for the companies that fit the criteria (H3)

- Statistical analysis assuming only companies that selected “We have heard of the term but are still gathering information about it” as being their knowledge of the Industry 4.0 (H3);

		A	B	C
N	Valid	58	62	60
	Missing	9	5	7
Mean		3,2304	3,3427	3,3929

Table 23 - Mean values for the companies that fit the criteria (H3)

- Statistical analysis assuming only companies that selected “We have no knowledge of the phenomena” as being their knowledge of the Industry 4.0 (H3);

		Statistics		
		A	B	C
N	Valid	16	15	15
	Missing	29	30	30
Mean		2,6580	2,7844	2,8120

Table 24 - Mean values for the companies that fit the criteria (H3)

Hypothesis 4

- Statistical analysis assuming only companies that operate in favorable areas

		Statistics		
		A	B	C
N	Valid	52	53	52
	Missing	1	0	1
Mean		2,9755	2,9434	2,9780

Table 25 - Mean values for the companies that operate in favorable areas (H4)

- Statistical analysis assuming only companies that don't operate in favorable areas

		Statistics		
		A	B	C
N	Valid	92	96	96
	Missing	4	0	0
Mean		2,3814	2,4219	2,4762

Table 26 - Mean value for the companies that don't operate in favorable areas (H4)