UNIVERSITÀ DEGLI STUDI DI PADOVA

**DIPARTIMENTO DI SCIENZE ECONOMICHE E AZIENDALI
“MARCO FANNO”**

**CORSO DI LAUREA MAGISTRALE IN
BUSINESS ADMINISTRATION**

TESI DI LAUREA

“THE ECONOMIC IMPACT OF TIME ON LEAN PRODUCTION: STATISTICAL ANALYSIS OF ITALIAN MANUFACTURING COMPANIES”

RELATORE:

CH.MO PROF. ANDREA FURLAN

CORRELATORE:

CH.MO PROF. ADRIANO PAGGIARO

LAUREANDA: PAOLA PACCAGNELLA

MATRICOLA N. 1203191

ANNO ACCADEMICO 2019 – 2020

Il candidato dichiara che il presente lavoro è originale e non è già stato sottoposto, in tutto o in parte, per il conseguimento di un titolo accademico in altre Università italiane o straniere.
Il candidato dichiara altresì che tutti i materiali utilizzati durante la preparazione dell'elaborato sono stati indicati nel testo e nella sezione "Riferimenti bibliografici" e che le eventuali citazioni testuali sono individuabili attraverso l'esplicito richiamo alla pubblicazione originale.

The candidate declares that the present work is original and has not already been submitted, totally or in part, for the purposes of attaining an academic degree in other Italian or foreign universities. The candidate also declares that all the materials used during the preparation of the thesis have been explicitly indicated in the text and in the section "Bibliographical references" and that any textual citations can be identified through an explicit reference to the original publication.

INDEX

LIST OF GRAPHS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Nowadays manufacturing companies must face an increasing worldwide competition, which puts them under a lot of pressure. In order to respond to this challenging market environment, many organizations find the solution in the adoption of lean tools and techniques. The lean practices aim to decrease costs and to be more efficient than competitors by the elimination of waste. But the definition of lean production is not straightforward because it refers to a completely new philosophy and approach. Therefore, the isolated implementation of a set of lean tools does not grant the expected results because lean is seen as an "integrated, complex management system that spans the entire company where all people at all levels have to be involved and committed to continuous improvement" (Fullerton et al., 2014). In relation to this topic, *Chapter 1* provides a comprehensive view of lean development in order to clarify what leanness means in organizational context. Moreover, the five lean principles and main lean concepts are illustrated as cornerstones and guide for companies performing the lean transformation.

The enhancements of operational performance on the short term using lean manufacturing are studied and proved by many authors, who focus their studies on operational speed, costs, customer response, quality and flexibility. Nonetheless, it is useful to investigate the effects of lean practices also on financial performance in order to examine whether lean manufacturing firms develop skills for creating permanent value. The results of these studies bring to different conclusions and the impact of lean approach on financial performance is not clear. The first part of *Chapter 2* illustrates controversial researches; on one hand, some of them depict a positive effect on financial measures, on the other hand, some results lead to opposite conclusions. An important element, which is usually neglected, is the role of lean maturity. Lean maturity cannot be reached overnight but it needs time, learning and training. A deep description of lean maturity and of the process leading to a good lean experience is contained in the second part of *Chapter 2*. The purpose of this work is providing a statistical analysis, which points out and emphasizes the role of time in the impact of lean adoption on firms' performance. Specifically, the analysis tries to study whether lean adoption influences positively the financial and economic performance over time.

The statistical analysis is feasible through the elaboration of a database containing information on 454 Italian manufacturing firms – mostly situated in Northern Italy – collected over a period of ten years. The information included in the database is described in *Chapter 3*. In the beginning all companies are analyzed in order to give a general insight of the sample. Afterwards, the data description shifts the focus on the characteristics of lean adopters and on the comparison between these lean adopters and non-lean adopters.

The information within the database are used to perform the empirical analysis, which is elaborated in *Chapter 4*. The analysis exploits the longitudinal feature of data, called panel data, and thus it uses both the time-series dimension and the cross-sectional dimension. The method chosen to investigate panel data is "random effects method" because it allows to examine also the impact of time-invariant variables. The study is carried out by building and running two regression models. Each of them has respectively the financial indexes Return on Equity and Return on Assets as dependent variable. The independent variables are represented by degrees of lean maturity in the sample. Particularly, the model compares financial performances of four different categories of companies according to the achieved level of experience in lean manufacturing. This categorization allows to understand whether there is an overall trend among these levels and whether this trend is significantly positive over time. The last part of the Chapter explains and justifies the choices leading to the final regression models.

Chapter 5 summarizes the outcomes of the empirical analysis and it discusses the results. The main findings of this paper suggest that lean companies experience a higher financial performance compared to non-adopter and lean companies with higher level of maturity perform better than lean companies with lower level of maturity. Eventually, limitations and further research opportunities are reported.

CHAPTER 1: THEORETICAL VIEW OF LEAN THINKING

1.1 The definition of lean thinking

In the first half of the twentieth century, the mass production became widespread in many western companies. This method is based on producing standardized products at high-volume at the expense of variety and customization and it uses unskilled workers performing simple and repetitive tasks. After the 1950s, the preferences of customers started to change significantly. Consumers wanted to have customized products and more sophisticated interests. This new market scenario put in crisis the mass production, whose goal was to have "acceptable number of defects, a maximum acceptable level of inventories, a narrow range of standardized products" (Womack et al., 1990). The new customers' mind-set was a big challenge and a struggle for mass producers, that could change the production process or add brand-new products only at very high costs and over a long period of time. Hence, there was the need for an innovative approach to the production that could satisfy the customer demand. This new method was elaborated in the Japanese automobile company "Toyota" by the production engineer Taiichi Ohno and the founder's family member Eiji Toyoda. They developed the *Toyota Production System (TPS)* which consisted of two main innovations. The first one was the elimination of waste. Ohno realized that this goal could be achieved through the just-in-time and through the autonomation. Making small batches reduced the carrying costs and it helped to identify any problem instantly. Hence, this mechanism led to a significant reduction of inventory, one of the cornerstones of the lean production. Toyota also emphasized autonomation, machines that can work autonomously with a little human touch. The second innovation was, indeed, about the role of people in the company. Ohno understood that the Japanese system allowed a different exploitation of the wide spectrum of workers' skills. Unlike the Ford's system, where operators executed repetitively only few tasks, Toyota encouraged "team-based problem solving, job enrichment (by including maintenance and set-up tasks in operators' jobs), job rotation and multi-skilling" (Slack, Brandon-Jones & Johnston, 2016). In this scenario, the team-group had not only to cooperate to perform the assembly steps in the best way, but also to suggest improvements for the process; the goal of this approach was to make the workers part of a community. In this community every worker, not necessary the senior manager, had the role of monitoring and of disclosing whether a problem emerged. In this case, the team would work together on the problem. To do this, Ohno designed "the five whys" problem-solving approach, " producer workers were taught to trace systematically every error back to ultimate cause by asking 'why' as each layer of the problem was uncovered, then to device a fix, so that it would never occur again" (Womack et al., 1990). Thanks to these innovations, the company could offer in less time twice the cars produced through the mass production with the same budget and it could reach more flexibility and superior reliability. The Toyota Production System laid the basis for the modern concept of the lean manufacturing. The first definition that can be found in the literature describes that "compared to mass production it uses less of everything - half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products" (Kracfik, 1988).

Giving only one definition of what we talk about when we mention the lean management could be cumbersome because this concept evolved over time; therefore, it can be analysed from different perspectives. First of all, it is considered a philosophy according to which all the steps in the production must be executed in the best way, " do more and more with less and less - less human effort, less equipment, less time and less space" (Womack et al., 1996), in order to meet the customer's needs and preferences. Lean is also a method of planning and controlling operations because many lean principles define how to manage and to coordinate the operation's flow always with the purpose of eliminating the waste. Finally, lean is viewed as a set of tools and techniques that follows the lean philosophy. Hence, these three different perspectives are not exclusive but are intercorrelated (cf. Slack, Brandon-Jones & Johnson, 2016).

1.1.1 Lean terminology

The birthplace of lean thinking is Japan, as illustrated in the previous paragraph. This kind of production has been spread and implemented all over the world but certain Japanese terms have taken root when people talk about lean production. Hence, the comprehension of this terminology is essential to understand lean management.

The first Japanese term to understand is *muda*, a frequently used word in lean terminology, which corresponds to the English word "waste". The purpose of the lean production is maximizing the customer value while minimizing *muda,* and that is the reason why lean is also known as "manufacturing without waste" (Taj & Berro, 2006). By waste we mean all those activities which do not add any value but which consume resources, thus are sources of costs. Taiichi Ohno realized promptly the importance of the waste in the production, especially for his *Toyota Production System*, and he was the first who classified the most crucial types of waste:

- waste of overproduction, which means producing more than what it is needed and more than what customers want. It is seen as the main source of *muda* and it can result from wrong forecasts;
- waste of waiting, which spots wasted time or any delay that slows down the production and the assembly line;
- waste of transportation, which identifies the resources spent on moving items around the operations;
- waste of inventory, even if it can be of different nature -raw materials, final products, materials within the process- keeping inventories leads to substantial costs;
- waste of motion, which indicates any useless movement of operators that does not create value;
- waste of over-processing, which is related to obsolete steps of the production process;
- waste of defects, which is caused by poor quality of the products or of the service.

All these inefficiencies lead to cost increase that has repercussion on the final price but the customer is not willing to pay more due to *muda*. Another two words connected to *muda* are *mura* and *muri*. The first one -*mura*- is translated as "unevenness", "irregularity" or "non-uniformity". This concept indicates the necessity to eliminate all those fluctuations in scheduling and in production, which are not due to customer's demand. The second one -*muri*- refers to the English translation "overburdening", thus the exaggerated exploitation of machines and workers in unsustainable way. To avoid this problem, lean management needs to design the production process in order to distribute and not to overburden employees (cf. Shamah 2014). All these three types of waste, *muda, mura* and *muri,* are often identified as the 3M of lean management.

The identification of waste is fundamental in order to solve this problem and this is possible performing the *Gemba Walk,* another recurring Japanese word, which in English means "real place", in relation to the actual place where value is created in the company. The activity follows the "go-and-see" approach to be able to seek out waste. More specifically, this means that workers, leaders and managers must walk the production process to discover problems, to examine issues and, finally, to fix them (cf. Castle & Harvey, 2009). The *Gemba walk* has two main advantages. First of all, it is an efficient technique to implement regular improvements with the help of team players because they are in constant touch with each other and they can solve issues as soon as possible. Consequently, strong relationships and respect among team members are built. Secondly, the efforts of team players are aligned and this is necessary for the effectiveness of the *Gemba walk* and for waste recognition (cf. Tyagi et al., 2015).

1.2. The lean principles

In the 1996 James Womack and Dan Jones in their book "*Lean Thinking: Banish Waste and Create Wealth in Your Corporation*" make explicit and analyse those principles that have been silent previously and that allow any company across different industries to reach leanness. The aim of the study is to provide a guidance for actions of those who want to implement lean production. Without the understanding of these principles, many managers implement some tools and techniques of the lean production but they do not get the expected results because they do not have the grasp of it. The five principles can be shortly described: "precisely *specify value* by specific product, *identify the value stream* for each product, make value *flow* without interruptions, let the customer *pull* value from the producer, and pursue *perfection*" (Womack at Jones, 1996).

1.2.1. Specify Value

The goal of lean management is the maximization of value. Therefore, specifying the value is the first step to implement lean thinking and to eliminate *muda*. The value is driven by the ultimate customer in terms of clear-cut goods or services, that satisfy the customer's needs, given a price and a specific time. Hence, we can say that "specifying value in interpersonal relationships means simply to understand the wants and expectations of the people that we interact with" (Emiliani, 1998).

A very common mistake is giving priority to the point of view of internal departments of the firm and not to buyer's point of view in order to create value. Defining what the customer values the most - quality, price, brand recognition, fast delivery etc.- is crucial for the success of lean implementation. In the strategy of any firm the customer value must be specified and only with this necessary information we can apply lean management. However, the identification of customer value is not always straightforward for the producer that creates the value. Rarely producers think out of the box, they only reproduce what they are already offering with a wider variety. Instead, it is fundamental that companies challenge the classic definitions of value and that they try to investigate a redefinition of it, by talking to customers and to other firms of the value stream (cf. Womack and Jones, 1996).

1.2.2. Identify the value stream

This second principle means to have clear all the steps and activities that are necessary to make a product, that can be a good, a service or a combination of these two. The main practices of the value stream are three: "*the problem-solving task* running from concept through detailed design and engineering to production launch, *the information management task* running from order-taking through detailed scheduling to delivery, and *the physical transformation task* proceeding from raw materials to a finished product in the hands of the customer" (Womack and Jones, 1996).

Furthermore, the value stream analysis highlights different types of activities. The first one is the value-added activity, which refers to activities that create value doubtless and that must be performed in the best efficient way. Then we have activities that do not create value but that cannot be eliminated, hence they must be minimized as much as possible. Lastly, there are activities that do not create value and that can be avoided, hence they must be eliminated. Mapping the value means not only identifying the physical production process but also mapping the information process that we need to plan our production.

1.2.3. Flow

After having specified the value and identified the value stream, the next step in the lean management is to make activities flow continuously. Flow refers to "the progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials into the hands of the customer with no stoppages, scrap, or backflows" (Womack and Jones, 1996). Until before, the most popular method used in the mass production is batch-and-queue manufacturing method, that follows the principle of producing large batches and sending them in the queue before the next step. The result of this approach is long waiting time and, therefore, expensive inventory. By adopting single-piece flow, the company can avoid this kind of waste and it can flexibly respond to changes in the demand and to the need of variety. This approach is more customer-oriented than batch-and-queue because the latter is performed for the benefits of the producer not of the buyer.

1.2.4. Pull

According to the pull concept, the flow of production should be driven directly by the customer needs; thereby, the production is always subordinated to the arrival of customer demand. This means that companies start activities only when the customers want it and for what they want, which makes the demand also much more stable.

The logic behind the pull system differs from the one behind the push system, used in the mass production. The three main differences are:

- the connection with the upstream and the downstream: in the push system there is no connection, while in the pull system each step is activated by downstream information;

- the need of Material Requirement Planning: the push approach relies on it, whilst the pull one does not need it;

- the role of forecast, using the pull logic: the production is based on forecasts, that are useless when the push logic is used.

In this regard, it is necessary to explain the *Kanban*[1] system, developed by Taiichi Ohno. *Kanban* is the tool that is used to control the inventory in order to have what you need, when you need it and at the right quantity.

1.2.5. Pursue Perfection

The previous four principles have one thing in common: all of them want to improve the production as much as possible in order to reach perfection. Nevertheless, in the real world perfection is impossible to reach but lean firms strive to improve and to eliminate waste as much as possible. In Japanese this concept is described by the word *Kaizen*, which literally means "change for better". Kaizen refers to a continuous improvement rather than breakthrough improvement. Continuous improvements imply small, frequent and cheap changes that are done every day, everywhere and by everyone. The path that Kaizen follows is the PDCA – Plan, Do, Check, Act - cycle, which describes the steps that a lean company must stick to in order to realize continuous improvements.

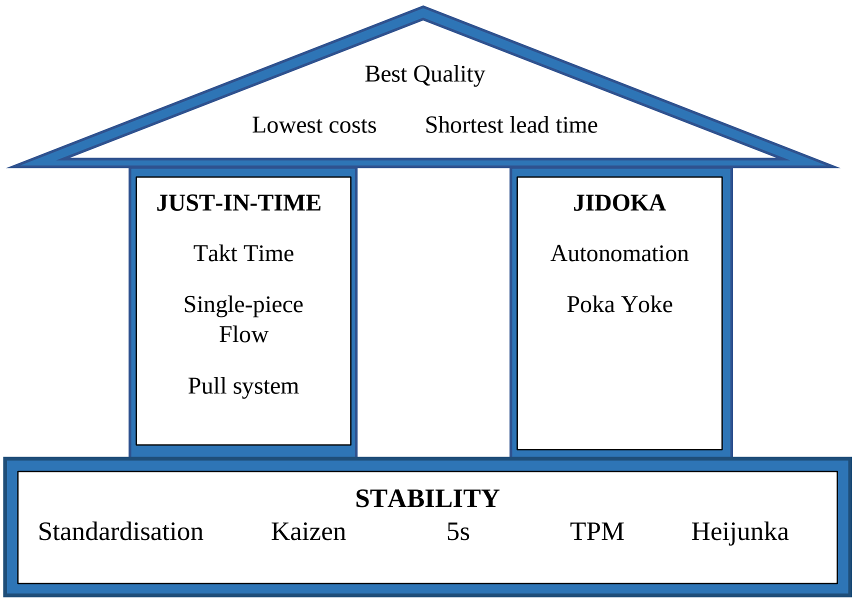
[1] *Kanban is* a Japanese word, which means "signboard" or "billboard".

Pursuing perfection is feasible also because the activities become transparent in the lean production, every member can see what is happening and can spot possibility of creating value (cf. Womack and Jones, 1996).

1.3 The Toyota Production System House

As already mentioned, the Toyota Production System – or TPS – is the forerunner of the lean thinking. All those companies, that want to be lean and look at Toyota as a model, must first investigate tools and techniques that Toyota uses. Therefore, it is essential to analyse more deeply the most relevant elements on which the Toyota way is based. The Toyota Production System is represented as a house as we can see in *Figure 1*. Commonly the shape of a house is used because it is allusive: only with strong pillars and good foundations the building can be solid and stable. In this case, the foundations of the building are standardized processes. Without them, we could not have two main pillars, which are Just-in-Time and Jidoka. These three main parts must work together in order to succeed in reaching better quality, lower costs and lower lead time (Liker and Morgan, 2006).

Figure 1:TPS House



Source: *"The Toyota way in service: The case of lean product development"*

1.3.1 Stability and Heijunka

The first part of Toyota Production System refers to having stable processes, which are reachable through *Standardisation* and *Kaizen*. These two concepts are correlated and Kaizen would not exist without Standardisation. We can say that "standardisation is the essence of lean methods and forms the basis of continuous improvement" (Shang & Low, 2014) because it allows workers to follow certain paths that are considered the best in terms of quality, time and costs but, at the same time, the workers are able to spot opportunities and to improve standards. The improvement is also done applying the so-called *5s method,* which refers to first letter of five Japanese words (cf. Chapman, 2005):

- *Seiri* – in English sorting-, this first step means selecting what is useful for the production and what is not;

- *Seiton* – simplifying – makes the employees put in order and organise the useful materials to minimize the costs of transportations and movements;

- *Seiso* - sweeping – refers to keeping the workplace clean and in order, hence the inefficiencies cannot be hidden;

- *Siketzu* – standardising - represents the need of deciding standardized processes that must be followed;

- *Shitsuke* - self-discipline - means that the company must sustain the processes at all level and make them deep-rooted.

When the stability is the goal, also the priority that is given to maintenance can make the difference. Manufacturers realize that organization of maintenance can be a strategic element to cut costs and wastes. Canonical meaning of maintenance is fixing broken items and traditional maintenance is activated when problems arise, that is the reason why this method is reactive. The need of a new, more efficient approach leads to total productive maintenance. In contrast to traditional method, total productive maintenance is used on a daily basis in a preventive way. Preventive maintenance "is a kind of physical check-up of the equipment to prevent equipment breakdown and prolong equipment service life […] may include equipment lubrication, cleaning, parts replacement, tightening, and adjustment" (Ahuja and Khamba, 2008). TPM is performed by all workers, who must be trained in relevant maintenance skills, autonomously through small group activities but it finds its roots in designing machines because they must be resistant and easy to maintain.

Moreover, another important element of the foundations is the *Heijunka,* which means levelling. In order to reach stability and standardisation, it is necessary that any lean company minimizes the fluctuation of production and establishes a levelled work load and stream of orders. This technique has the benefit of reducing *mura* (cf. Liker and Morgan, 2006).

1.3.2. Just-in-Time

The first pillar of the TPS house is the concept of Just-in-Time. Womack and Jones (1996) identifies it as "a system for producing and delivering the right items at the right time in the right amounts". Concretely, this method starts the manufacturing only at the moment when the customer's order arrives. Hence, the product is made only when it is needed in order to reduce inventory and to be more flexible. The benefits of the pillar are several, among the most relevant we must mention the elimination of waste, improvement of productivity, identification of bottlenecks and the reduction of delivery lead time. This philosophy is the opposite of Just-in-case -or JIC- system, where the products are already done before the order is received (cf. Kootanaee, Babu, and Talari, 2013).

The elements that compose Just-in-Time are takt time, single piece flow and pulling of materials from upstream processes.

The takt time is the speed of the flow and it is calculated dividing the available production time by the customer demand. It must not be confused with the cycle time, which is the production time. The purpose of lean companies is to equal the takt time and the cycle time in order to have a smooth flow. Furthermore, just-in-time is implemented also through one-piece-flow, which means moving a workpiece at a time through the operations; this movement is facilitated if the manufacturing cells are situated one close to each other.

1.3.3 Jidoka

The last pillar is less known than the first one but it is equally important. This concept is developed by Sakichi Toyoda and it is also called Autonomation, which means automation with human intelligence. Hence, this means "transferring human intelligence to automated machinery so machines are able to detect the production of a single defective part and immediately stop themselves while asking for help" (Womack and Jones, 1996).

Jidoka is achieved through three different principles. The first one is the separation of human work from machine work because having one man for each machine who monitors constantly was considered a huge inefficiency. The automated machine can detect operating problems and stop itself as soon as they occur (cf. Soliman, 2016). Alerting work team of production abnormalities and signalling the need for help are facilitated by the *Andon* system, which is the second principle of Jidoka. Andon board is a control tool that gives visual, audible and immediate warnings to the team workers and the aim of it is to build in quality and to prevent that defects reach customers. The last principle is *Poka-Yoke*: a very simple and effective technique which prevents errors made by operators, which for example can be originated by choosing the wrong part, leaving out a part or installing an element backwards. Therefore, *Poka-Yoke* is an error-proofing that makes the whole process more robust. (cf. Wilson, 2010).

CHAPTER 2: EFFECTS OF LEAN STRATEGY ON ECONOMIC AND FINANCIAL PERFOMANCE

2.1. Literature review

Nowadays every firm that wants to stay in the market faces an increasing worldwide competition and a huge pressure due to the fact that it must always achieve better results and improve efficiency in terms of quality, costs and lead time. In this scenario lean production techniques and principles are implemented by several organizations in order to have superior performance (cf. Garza-Reyes et al., 2012). Many authors investigate the positive link between the lean production and the operational performance (Rahman et al, 2010; Shah and Ward, 2007; Bhasin, 2012; Cua et al., 2006; Taj and Morosan, 2011; Lawrence and Hottenstein, 1995; Thun et al., 2010; Bortolotti, at al., 2013; Searcy, 2009; Hallgren and Olhager, 2009; Behrouzi and Wong, 2011; Rivera and Chen, 2007; Dora et al., 2013; Karim and Arif-UzZaman, 2013), using different measures to analyse the impact, that has positive effects on various aspects, for example on flow, quality, inventory turnover, product volume and many others (cf. Belekoukias et al., 2014).

If on one hand the operational changes are the cornerstones of the lean transformation and they are easy to identify and to monitor, on the other hand the impact of lean production on the financial performance is usually not straightforward, also because it could depend on exogenous elements (cf. Losonci and Demeter, 2013). In the literature we can find two main currents of thoughts. The first one declares that there is a positive link between the introduction of lean and the financial performance; the second one does not see any relationship between the two items.

The most important investigations of those that argue the presence of beneficial effects are listed in *table 1.*

__Table 1__:List of researches that prove a positive impact between financial performance and lean implementation

Authors	Industry	Sample	Financial measures	Conclusions
Inman and Mehra (1993)	-	U.S. manufacturing firms (N=114)	ROA ROI Total costs	The investigation shows that financial performance improved thanks to the adoption just-in-time.
Callen et al. (2000)	Automotive	Canadian manufacturing plants (N=100)	Profit and contribution margin	Organizations that implemented JIT have minimized costs and maximized revenues.
Kinney and Wembe (2002)	-	U.S. manufacturing firms, which implemented JIT (N=201)	ROA Asset turnover Profit margin	The study highlights that lean adopters have outperformed non-adopters, with more advantages for first movers. There is not superior performance for small companies.
Fullerton et al. (2003)	Food; textile; furniture; paper chemicals and allied products; rubber products; primary and fabricated metals; industrial machinery; electronics; motor vehicles and accessories and other manufacturing.	U.S. manufacturing firms (N=253)	ROS ROI Cash flow margin	Empirical results show strong positive link between the financial performance and the degree of JIT implementation, the quality dimension and JIT purchasing.
Yang et al. (2011)	Fabricated metal products; office, accounting and computing machinery; radio, television and communication	International manufacturing firms (N=209)	ROS ROA	Lean manufacturing practices have important and positive impact on the financial performance; but, by implementing these practices, firms must

	equipment and apparatus; medical, precision and optical instruments; watches and clocks.			also take into consideration environmental management practices.
Hofer et al. (2012)	24 (not specified) four-digit NAICS[2].	North American manufacturing firms (N=1421)	Net sales Sales growth ROS	The internal lean practices have positive impact on financial performance and this link is mediated by inventory leanness.
Furlan and Galeazzo (2017)	Products of systems to insulate doors and windows; iron, steel and other metals; automation systems; electrical and electronic instruments for heating and air quality appliances; wine bottling; office furniture; batteries, cells and rechargeable batteries and other manufacturing.	Northeast Italian manufacturing firms (N=19)	ROA Growth rate	The implementation of lean manufacturing must be carried out by choosing configurations of lean bundles that lead to success. None of lean bundle alone can be the reason of a good financial performance, but lean bundles must be complemented by other lean bundles.

Source: Personal elaboration

In the table above there are different kind of analysis, elaborated studying disparate firms working in many industries. All the results lead to state that there is a positive link between the financial performance and the lean production practises, with slightly different facets.

The study of Jeffrey L. Callen, Mindy Morelb and Chris Faderc (2000) wants to illustrate how the risk and profitability, connected to just-in-time practices, affect the financial performance

[2] "North America Industry Classification System" (which acronym is NAICS) is the industry categorization by type of economic business, which is used in United States of America, Canada and Mexico.

of firms. The role of risk is essential in this study because the risk that shareholders bear could change when there is a variation in the operational technologies. The paper illustrates that benefits of lean manufacturing not only cover this risk but also outperform it (cf. Callen et al., 2000). Two years later another analysis compares adopter and non-adopters of just-in-time methods to investigate whose financial results are better among the two groups of firms. Also this investigation shows that manufacturing firms have higher return on assets if they are adopters. Both the asset turnover and the profit margin are improved, particularly the latter (cf. Kinney and Wembe, 2002).

Fullerton et al. (2003) survey 253 American manufacturing firms of different sectors to see the impact on financial performance at three levels. The degree of lean production (1), the quality dimension of just-in-time (2) and the just-in-time unique indicators - Kanban system and JIT purchasing- (3) have a “positive relationship with firm profitability”.

Another dimension is added in the analysis of Yang et al. (2011): environmental management. These authors want to understand the connection between the lean manufacturing and environmental management and the impact of each of them on the financial performance. The first connection is confirmed in the data analysis and it finds further confirmation also in the previous literature because lean manufacturing aims to reduce waste and inefficiency, which is in line also with the environmental management’s purpose. Lean manufacturing and environmental management impact positively, even if in different ways, also on financial performance according to this analysis.

The research conducted by Hofer et al. (2012) focuses its attention on the “mediating role of inventory leanness”. The study distinguishes lean practice internally and externally and it shows that both have positive consequences on financial dimension. The role of inventory leanness is found to have a positive relationship with external lean practices and negative with internal practices. This specific finding is justified by saying that the firms implement internal lean practises if they notice to have low level of inventory leanness; however, this relationship results to be unexpected.

The last study taken into account is conducted in Italy. From the analysis, it emerges that different sets of lean bundles are associated to different financial performance of lean manufacturing firms. These conclusions lead to some main implications. First of all, the lean bundles must be implemented together with other lean bundles to have successful performance, even if there is not a unique right combination. Second, the study tries to identify the mix of bundles, which could bring beneficial financial results. Therefore, managers should focus their attention and their investments on complementary lean bundles (cf. Furlan and Galeazzo, 2017).

Having a clearer view of those studies that support the hypothesis according to which financial performance and lean manufacturing have a beneficial link, it is important also to list -*Table 2*- and to illustrate the main analysis that sustain the opposite effect in order to have a wider comprehension.

Table 2*: List of researches that prove a null or negative impact between financial performance and lean implementation*

Authors	Industry	Sample	Financial measures	Conclusions
Huson and Nanda (1995)	Textile products; paper and allied products; printing and publishing; chemical and allied products; stone, clay and glass products; industrial machinery and equipment; fabricated metal products and other manufacturing.	U.S. manufacturing firms (N=55)	Inventory turnover EPS Cost per sales dollar Unit margins	In this work we can see a mixed effect, but the adoption of just-in-time has a negative impact on profitability.
Balakrishnan et al. (1996)	Furniture and fixtures; rubber products; primary metal industries; fabricated metal products; industrial machinery; electronics; motor vehicles and accessories; instrumentation; other manufacturing.	Manufacturing firms (N=46)	ROA	The research demonstrates that better inventory management does not imply a better ROA.

Lewis (2000)	Electronic and fasteners components	Selected three cases respectively in UK, Belgium and France	Total sales Gross annual profit	The comparison between three firms in Europe shows that the one which has not lean production sees both the financial measures grow.
Ahmad et al. (2004)	-	U.S. manufacturing firms (N=86)	Operating profits Profit to sale ratio Cash flow from operations ROI	Short-term benefits of lean implementation could finally arm the firms on long-term horizon. Further analysis shows that there is no relationship between lean practices and financial performance.
Bevilacqua et al. (2017)	-	Italian manufacturing firms (N=254)	Sales growth	Lean practices have not direct relationship with company sales growth. This result is caused by lack of training and education of operators and superficiality of implementation.

Source: Personal elaboration

In *Table 2* there are five disparate analysis that express, some of them stronger than others, a negative link between the two variables. The more moderate study is the first one, conducted in 1995. It does not deny beneficial effects of lean on company performance, but the lean manufacturing companies experience an increase of 1,15% on unit costs, while the industry has a mean of +0,73%.

The work of Balakrishnan et al. (1996) is usually mentioned in many papers as steady and representative support of thesis and it declares a negative impact between business performance and lean adoption. In order to have more credible results, the authors consider also the role of customer concentration and of cost structure. Companies with wide customer base have less pressure on adoption of Just-in-time to meet the customer demand; in any case these "free" firms, as they are called in the analysis, show more ability to have financial gains from just-in-time. Instead, lean companies with high committed costs do not have lower ROA than those that have low committed costs. On average, the analysis declares that there is not a significant relationship between ROA and adoption of lean procedures.

Another supporter is Michael Andrew Lewis (2000), who asserts his scepticism in his paper by stating that lean benefits depend on "particular market conditions at a specific point in time" (Lewis, 2000). This statement is upheld by comparison among three European firms that the author picks as models: company A and company B invest a lot on lean implementation and they have a low profitability due to disadvantages connected to conversion into lean firms; whilst company C, which decides to depend much less on lean, has a growth in profitability.

The approach of the paper written in 2004 is unconventional and it considers psychological effect that lean improvement gets on company perception of managers and stakeholders. Hence, the positive impact of lean results to be more an impression than a concrete result. Moreover, the real and positive impact of short-term could finally hinder and damage the firms' financial performance on long-term (cf. Ahmad et al., 2004).

The last analysis illustrated in *Table 2* studies 254 Italian firms. It emphasizes the importance of environmental conditions and contextual elements and shows that lean tools are not directly the cause of company growth performance. The authors try to give an explanation to this result by interviewing 39 managers of different industries. They reveal that there are many other elements that influence and limit the success of lean adoption.

This brief literature review shows the two main viewpoints by examining companies scattered around the world with different levels of leanness and different levels of experience over time. Anyway, the role of time is not always taken into consideration and this paper aims to deepen the function of maturity, which implies the role of learning, for lean manufacturing firms.

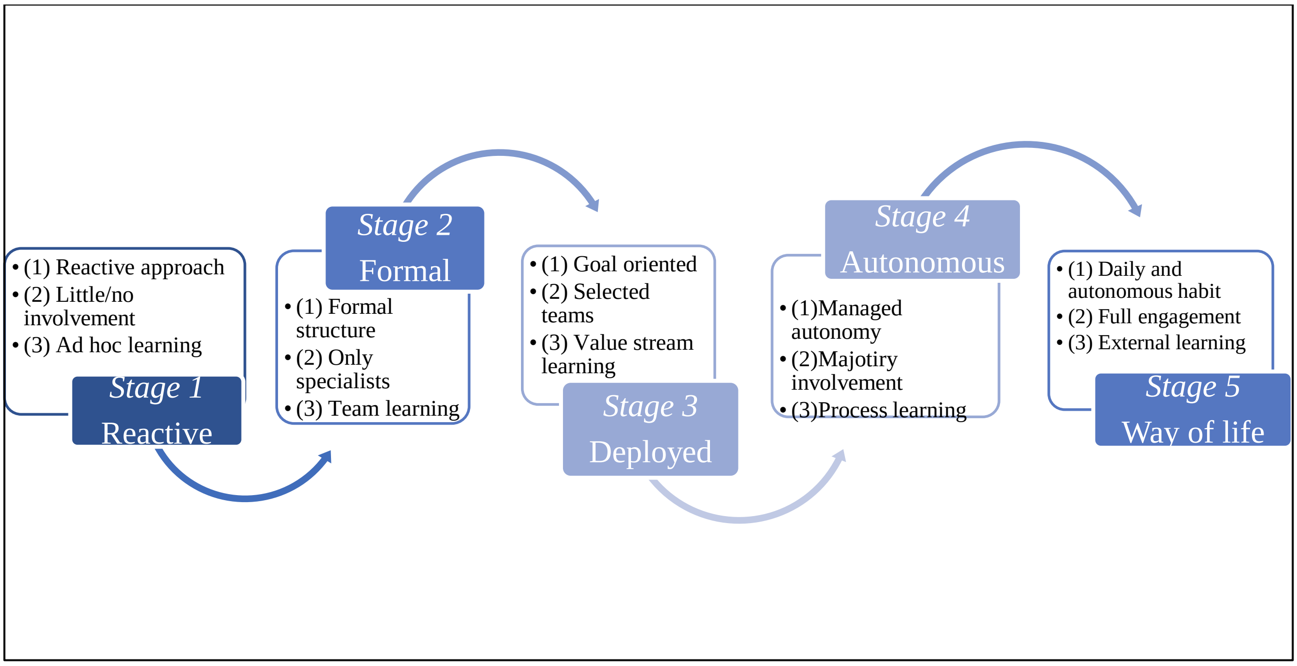
2.2. Definition of lean maturity

Antithetical conclusions in interpreting financial performance can be the consequence of analysing several lean companies that develop lean bundles with different timespan of experience. Therefore, it can be stated that companies have different maturity. Lean maturity is described as "the number of years a firm has been implementing lean manufacturing" (Galeazzo, 2019). Nesensohn et al. (2014) suggest that mature organisations are identified by consolidated behaviours, automatic processes, defined roles and responsibility. They also easily attract resources and gain established goals.

Lean maturity cannot be successfully reached overnight but it needs time in order to have lasting and sustainable results. Therefore, lean practices are deployed progressively, step-by-step, following a path that allows companies to have a rewarding maturity. If companies have not a clear sequence of action helping in the development and exploitation of lean in a more efficient way, they just add lean bundles without following criteria and without adapting the culture and behaviours (cf. Capgemini, 2005). Many authors try to answer the questions in the field of lean strategy adoption, by theorizing maturity models.

Hines (2010) designs a five-level model, each level represents a different level of maturity, which is based on three crucial characteristics: (1) ways of working, (2) employee engagement and (3) share best practice; every step has a different development in relation to these three factors. In *Figure 2*, the five stages are summarised and they are associated to the three key elements already mentioned. According to Hines, employees must gradually be involved in lean change and eventually every part of organisation experiments and shares improvements regularly and naturally (cf. Hines, 2011).

Figure 2: *Lean maturity assessment model*



Source: Hines (2010, p. 61)

Alternatively, the five steps are also presented and described in another way, deriving from observations of twelve Danish companies, which are implementing lean. The investigation points out common trends and behaviour, especially when the organizations have not deep knowledge of lean tools (cf. Jørgensen et al., 2007):

1. *Sporadic production optimization*: in this phase there are rare and sporadic attempts of optimization, which are not part either of a bigger picture or of a strategic plan. These efforts do not contemplate the involvement of workers but of the main leaders, who are experts, as in the lean maturity assessment model, outlined by Hines (2010).
2. *Basic lean understanding and implementation*: unlike the previous step, this stage represents the starting point of lean adoption for the organization, which consists in basic training and pilot projects.
3. *Strategic lean interventions*: gradually all projects and activities are organized in relation to established goals, compliant with lean philosophy. Lean principles are accepted at each level of organization.
4. *Proactive lean culture*: lean tool and techniques are fully understood and used daily in every part of organization by workers, who are asked to develop improvements. Anyway, these lean activities are only internal in this phase.
5. *Lean in EME (Extended Manufacturing Enterprise):* in the last stage the long-term results of lean activities are finally tangible. The lean strategy now is also external: knowledge and improvements are shared across organization's boundaries in order to create an inter-organizational network.

2.3. Lean maturity and financial performance

Although lean manufacturing is normally associated with initial growth in productivity and in quality, the central issue is whether this improvement is long-lasting, hence whether it is sustainable over time (cf. Poksinska & Swartling, 2018). Some studies suggest that at the beginning lean production has promising results but, when it reaches a certain maturity, lean companies starts to face difficulties in maintaining these standards and so they start to regress to the starting point and, in some critical situation, to deal with poorer business performance (cf. Keating et al., 1999).

According to Ahmad et al. (2004), lean maturity is not correlated to positive financial results because the research shows no causal relationship between just-in-time elements and financial performance. The authors also state that short-term positive achievements could be eventually misleading because they would cover latent danger in terms of performance for lean companies.

The thesis that companies with more experience have higher financial results is refused also by Jacobs et al. (2015), who analyse different financial measures between earlier and later adopters. "Early adopters of innovations typically enjoy first mover advantages due to novelty and to the development of advanced capabilities. In addition, institutional theory suggests that early adopters are more likely to adopt for efficiency reasons, rather than the normative, mimetic, and coercive pressures that often drive late adoption. These quasi-monopoly and motivational advantages suggest that early adopters of innovations would gain greater benefits than late adopters." (Jacobs et al., 2015). Nevertheless, the study shows less-mature firms experience more gains than more mature ones in terms of Return on assets on multiple-year basis, even if companies of different industries and size have slight variations. Similar conclusion is set forth in another study that compares companies with different level of maturity, examining change in sales and in cost per dollar of sales. The results show no difference between the performance of earlier and later adopters (cf. Hendricks and Shingal, 2001).

Conversely, in the research of Corredor and Goñi (2016) earlier implementers get financial gains that later adopters do not get, which gives a beneficial role to lean maturity.

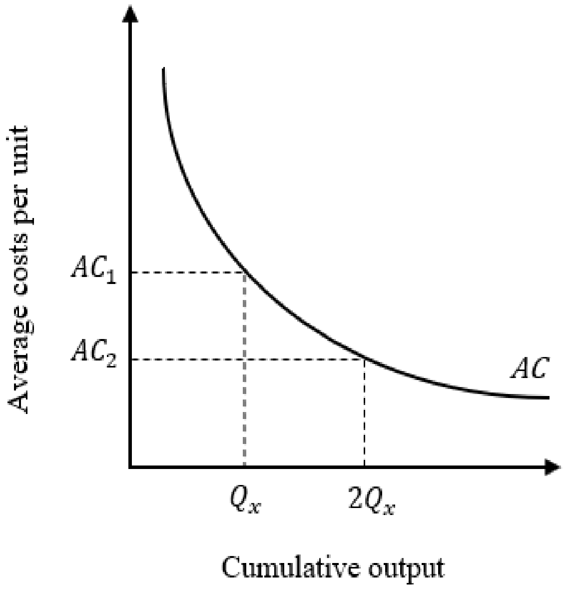
Other researches also support the positive impact of time on financial achievement of lean firms, by asserting that lean maturity allows companies to exploit better their resources, to solve more easily problems and difficulties thanks to past experience and to a more adequate implementation of lean techniques. The importance of lean maturity is stressed in the study conducted by Netland (2016), who identifies "the effect of implementation stage" as one of the critical factors for economic improvements. Galeazzo (2019) declares that lean maturity influences significantly the profitability growth (EBITDA/sales). Moreover, maturity must be high in order to impact positively the financial variable; whilst the wide extension of lean practices is not sufficient. This means that lean adoption should be carried out patiently, over time and not radically. Hence, at what speed companies should invest in lean production is another item that determines the sustainability of competitive advantages. This issue is treated by the theory of diseconomy of time compression. The proper definition is given by Cool et al. (2016):"time compression diseconomies are the additional costs incurred by firms seeking to quickly reach a given level of an asset stock when this stock could be accumulated more economically over a longer period of time". When diseconomies of time compression are low, latecomers can catch up in a short time earlier adopters with fewer cost penalties, in this case earlier adopters are less protected than those that operate in industry where resources and inputs needs time to be developed and to be accumulated, hence the diseconomies penalize heavily latecomers.

Moreover, Galeazzo (2019) focuses also her study on the moderating role between the financial variable and degree of leanness. The author specifies that high degree in terms of lean does not necessary imply high level of lean maturity, but the two elements are independent. This means that: "firms can display different levels of degree of leanness, irrespective of lean maturity. Therefore, the effect of degree of leanness on financial performance can be strengthened or weakened depending on how long a firm is implementing lean production" (Galeazzo, 2019). Literature offers, as usual, two main points of view; on one hand, there are researchers that support that the role of maturity does not moderate the link between business performance and lean activities (Swink and Jacobs, 2012; Brah et al., 2000); on the other hand, there are supporters of positive influence of lean maturity in the relationship between degree of lean and financial results (Jayaram et a., 2010; Netland, 2016).

2.4. The importance of learning in lean adoption

The five-step process to reach lean maturity underlines that learning has a key, strategic function. Without learning and education, lean maturity would not exist. Theoretically, the impact of learning has been studied and has been explained through the learning curve (or experience curve). The learning curve is a visual representation – *Figure 3* – which shows the advantages of accumulated knowledge and experience on firm performance. The idea behind is that workers need time to learn and master new tasks, which is possible only after numerous repetitions of those tasks. This gained know-how turns into lower costs, better quality or other benefits. The effect on lower costs is described as the decrease of average costs with the cumulative production, hence with more experience. Considering cumulative production is essential to distinguish this effect from economies of scale. Moreover, the effectiveness of learning benefits is measured through the slope of the curve, which is calculated as AC_2/AC_1 ; hence, the steeper is the slope the higher the benefit in terms of costs savings (cf. Besanko et al., 2004).

Figure 3*: The learning curve*



Source: Personal elaboration from Besanko et al. (2004)

The lean concept is the outcome of "a continuously iterating learning cycle that spanned decades. Thus, more than anything, it is this 'dynamic learning capability'" (Holweg, 2007). As such, the manner of adoption could influence either the failure or the success of lean management. One of the biggest challenges is to provide a lean learning pattern, which aligns individual learning and organizational goals (cf. Villalba-Diez et al., 2016). On one hand, it depends on what attitude people in organization have towards learning and changing; on the other hand, it depends on the approach and level of involvement of organization itself. As showed in the first phase of maturity assessment model, employees are still not involved in the process but they receive training after the definition of new organizational vision and goals. This step is considered critical for the right implementation of lean management and it has first to make people understand the relevance and usefulness of this organizational change. Without this understanding, organization would face higher reluctance and scarce motivation (cf. Appelbaum et al., 1998). Looking at Netland's (2016) study, training and education -both of managers and of employees- are necessary to reach success in lean implementation, emphasizing the help of external experts especially in the early stage of lean adoption.

Afterwards, employees are involved in lean change and they are asked to put teaching into practice. Arthur and Huntley (2005) find that the suggestions made by workers help to reach waste and cost reduction. Furthermore, it is not only the affective process – hence how people feel- that must be developed but also the cognitive process of managers and employees – hence how people think-. Even if workers are persuaded to put high effort on the lean change, a defensive reasoning could harm the success of lean adoption, "teaching people how to reason about their behaviour in new and more effective ways breaks down the defence that block learning" (Argyris, 1991). Therefore, there are two important learning, (1) conceptual learning and (2) operational learning. The first type aims to the acquisition of know-why, the cause-and-effect behind the processes and changes; whereas, the second one refers to the acquisition of know-how and to observations of results. Both must be implemented and Laprè et al. (2000) highlight that "in a production environment characterized by dynamic complexity and ambiguity such locally acquired know-how does not affect other people's strongly held beliefs, or myths. It takes conceptual learning to challenge myths". Moreover, conceptual and operational learning increase learning rate and, consequently, costs reduction.

Being a necessary element of lean maturity, learning has an impact on financial performance. The literature offers a broad spectrum of studies, most of the researchers have reached positive conclusions about the relationship between organizational learning and financial achievements. One of the first analysis, which investigates this relationship, is conducted by Dimovski (1994) and shows that organizational performance is influenced positively and significantly by organizational learning, analysing capital-to-assets ratio as financial measure. The study aims to test the hypothesis according to which organizational learning leads to competitive advantages compared with other competitors. Another study that finds beneficial correlation between the two items is done by examining eight organizations in Hong-Kong which have different learning styles (cf. Lam, 1998). Moreover, Dimovski et al. in 2004 demonstrates that there is a strongly positive impact of organizational learning and on both financial and operational performance. Those firms that commit to have higher learning rate get better financial performance in terms of profitability and value added per employee. A more recent investigation is done by Kaplan et al. (2014). In this case, organizational learning is divided into four different components and the impact on financial measures is studied considering separately each of learning components: (1) commitment to learning, (2) shared vision, (3) open-mindedness and (4) intra-organizational knowledge sharing. In the analysis, it emerges that the components (1) and (4) have a positive relationship with financial improvements; whilst the other two components- shared vision and intra-organizational knowledge- have not a determinant role in financial results. The last considered examination of the relationship between the two variables in this paragraph stands out from others because it displays an inverted U-shape relationship. The authors claim that any firm, that wants to have long-term prosperity, must develop new knowledge and new capabilities. According to Uotila et al. (2009), both lack and excess of exploration would bring to lower financial performance but still the optimal amount between two opposite behaviours needs to be reached. Finally, the research shows that most of the companies in the sample tends to select an amount which is below the optimal one.

To conclude, the literature review offers a wider understanding of the role that lean maturity and its elements play for lean organizations. Furthermore, the following analysis aims to deepen the function of time on economic performance for Italian lean manufacturing firms.
Given relevant insights of maturity, the present paper wants to study the impact of lean experience on economic performance of lean manufacturing companies:

Hypothesis: *Lean adoption has a positive economic and financial impact over time.*

CHAPTER 3: THE DATASET

3.1. Collection of data

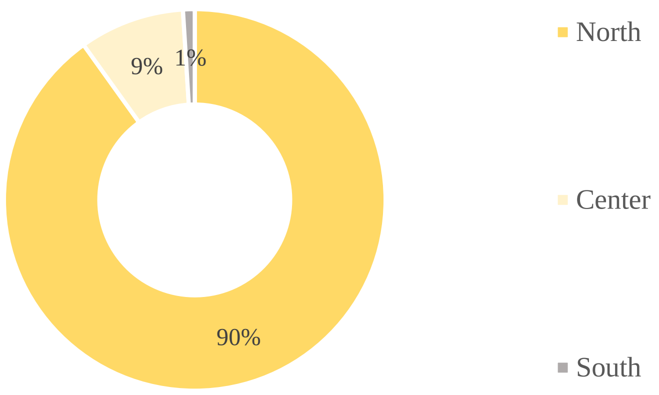
The investigation of lean impact on economic and financial performance has not a definitive solution. In the previous chapter, there are some researchers that analyse only one type of lean technique and others that do not take into account the role of time and probably this is one of the reasons why studies lead to different and contradictory results, as well as other contingent elements. This thesis aims to add a new perspective on this issue, by giving more importance to the role of lean maturity, thus to the role of time.

The data used for sample description and empirical analysis have two main sources. The first one is a survey, sent to Italian manufacturing firms through the online software Survey Monkey asking general information and insights about their acquaintance and exploitation of lean philosophy. The survey is developed by the Department of Economics and Management "Marco Fanno" of the University of Padua, with the support of CUOA Business School. All the collected data have been organized in an Excel file (cf. Boschetto, 2019).
Unfortunately, this year it has not been possible to have access to this source due to the current situation of emergency caused by the spread of Covid-19, which forces many companies to close and put others in distress. Therefore, data have been broadened only through the second source, which is the database called *AIDA* - acronym that stands for “Analisi Informatizzata Delle Aziende”- containing comprehensive information in terms of economic and financial measures and covering approximately one million Italian companies. This database is used to gather different economic indexes of companies in the sample, for example EBITDA, return of assets, return on equity, long-term debt and many others. One of the contributions of this thesis is completing and filling the dataset with this information related to more recent years.

3.2. Introduction to the sample

Once the data are collected, the companies of the sample are ready to be examined. The sample contains eventually 454 firms scattered throughout Italy. The first dimension to consider introducing the sample is the geographical localization of these 454 Italian manufacturing firms.

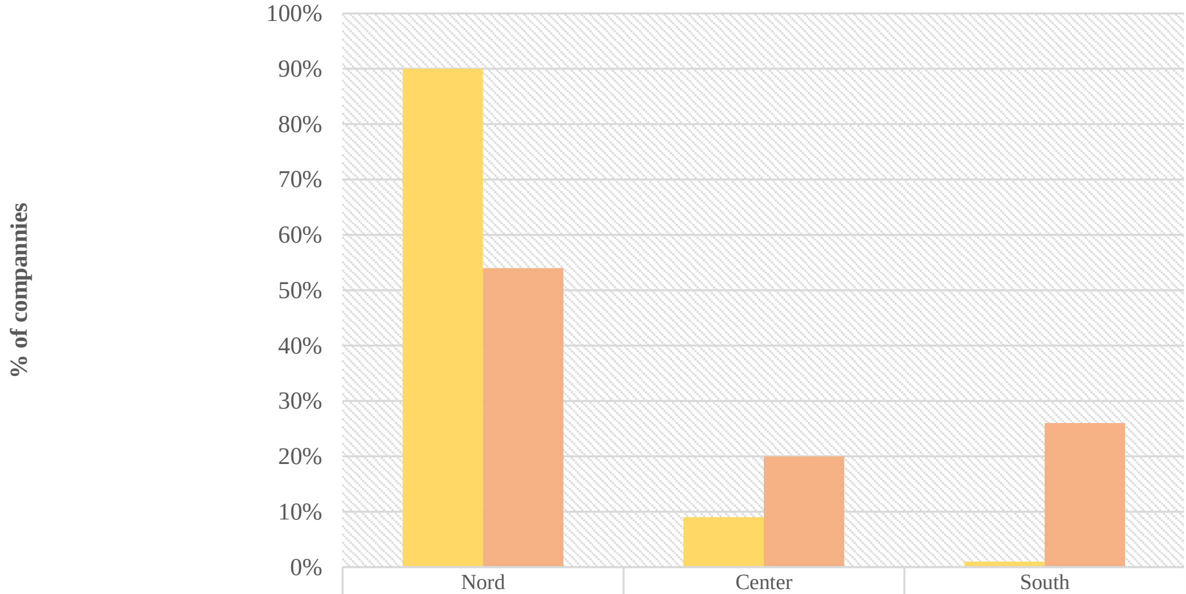
***Graph 1**: Distribution of the sample*



Graph 1 shows a strong majority (90%) of companies operating in the North of Italy; whilst the sample has a very small number of companies located in the Center and in the South, respectively only 9% and 1%. The general distribution in whole peninsula is a bit different in the manufacturing industry, which is identified by the ATECO[3] categorization in section C between the two-digit code 10 and 33. According to ISTAT data, in 2018 the total number of operating manufacturing firms is 377.698. Dividing the total number between the Italian three main areas, it results to have 203.976 firms in Northern Italy -more accurately 112.454 in the North-west and 91.522 in the North-east -, 79.093 in central Italy and 94.628 in Southern Italy. *Graph 2* shows the different proportions between the sample and the total number of Italian firms. The gap between regions is less pronounced for the total number compared to the gap in the sample, especially for the south area (which includes also the islands). Moreover, the total number of Italian manufacturing firms includes a higher percentage of companies situated in the South.

[3] Ateco code is a classification adopted by Istat used to identify economic activities through an alphanumeric combination.

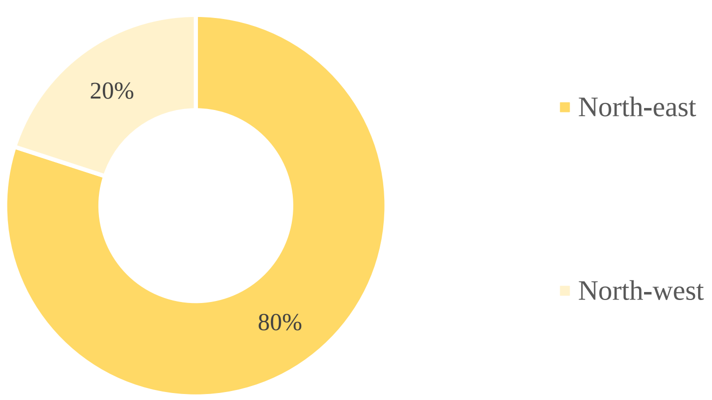
***Graph 2**: Geographical comparison between the sample and Italian manufacturing firms*



	Nord	Center	South
Sample	90%	9%	1%
Italian manufacturing companies	54%	20%	26%

Specifically, a further analysis can be done by dividing the sample of Northern Italy in North-west, which includes companies situated in Piedmont, Lombardy, Liguria and Aosta Valley, and North-east, which includes Veneto, Emilia Romagna, Friuli Venezia Giulia and Trentino Alto Adige. The total number of companies situated in Northern Italy is 413, among these 329 firms (80%) are in North-east of Italy, while 84 firms (20%) are in North-west, as depicted in *Graph 3*.

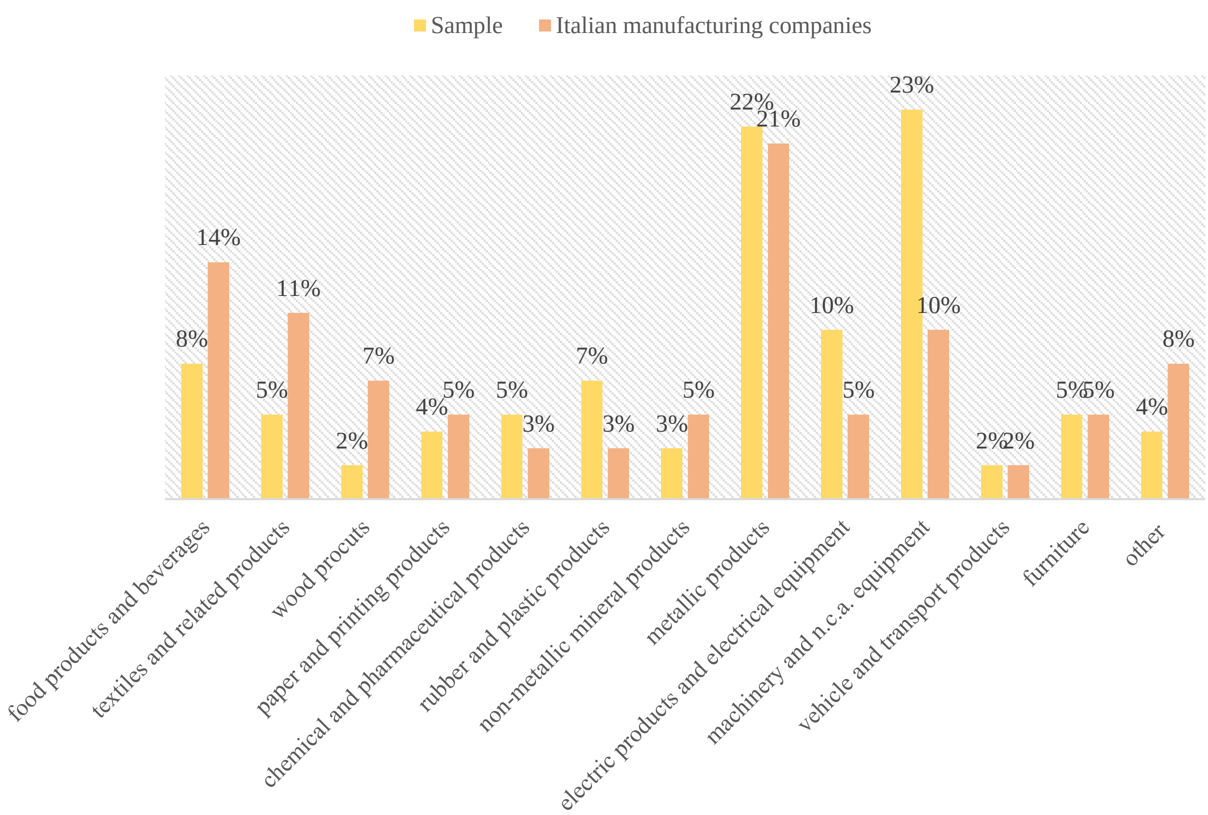
***Graph 3:** Sample distribution between North-east and North-west*



In addition to geographical distribution, another relevant characteristic of the sample is the distribution depending on the sector within the manufacturing section, since the sample contains firms belonging to manufacturing activities, which are subdivided in the ATECO classification and range between 10 and 33 of two-digits code. In the sample a substantial number of companies – 101 out of 448 – belongs to ATECO 28, which identifies manufacture of machinery and n.c.a.[4] equipment. The second largest group with 86 companies is ATECO 25, hence the manufacture of metal products. Other two big clusters are ATECO 27, manufacture of electrical equipment and non-electric domestic appliance, and ATECO 22, manufacture of rubber and plastic products. These two industries have respectively 37 and 32 companies in the sample. This occurs because companies taking part in the survey mostly belong to these three industries (cf. Boschetto, 2019).

In order to see if the sample is representative of the situation in Italy, *Graph 4* illustrates the comparison of the industry distribution between the sample, whose firms providing their ATECO code are 448, and Italian firms, whose total number is 342.019. The companies included in ATECO 12 -manufacture of tobacco products-, ATECO 19 - manufacture of coke and refined petroleum products- and ATECO 33- repair and installation of machinery and equipment- are discarded because the sample does not contain any firm of these industries.

***Graph 4**: Industry distribution in the sample and in Italian manufacturing firms*



[4] N.c.a. is an Italian acronym, which indicates those activities that are not coded anywhere else.

In *Graph 4* some industries are grouped together because they are part of similar sectors, for example food products and beverages are depicted in the same value, as well as chemical and pharmaceutical products, paper and printing products , textiles and related products and electric products and electrical equipment.

The comparison highlights that almost all sectors have similar percentage in the sample and in the overall Italian situation. Hence, the sample can represent at some extent the manufacturing industry that is present in Italy, although there is a massive difference between the percentage of machinery and n.c.a. equipment industry in the sample (23%) and in Italy (10%).

A further classification among different sectors can be carried out by considering the technological intensity of firms in the sample. The adopted classification Eurostat-OCSE categorises manufacturing firms in four different groups based on 3-digit level of NACE code[5]:

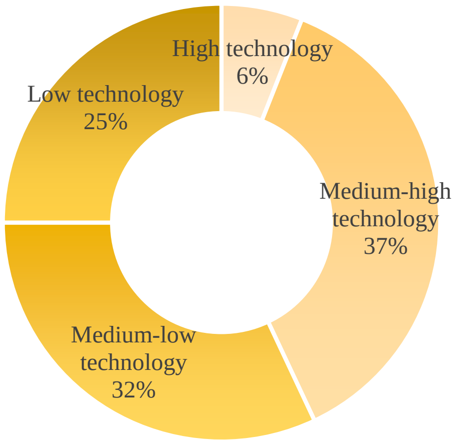
1. High intensity, the activities included in this group are manufacture of basic pharmaceutical products and pharmaceutical preparations (21), manufacture of computer, electronic and optical products (26), Manufacture of air and spacecraft and related machinery (30.3) and manufacture of medical and dental instruments and supplies (32.5);
2. Medium-high, all the sectors in this category are sector of chemicals and chemical products (20), of weapons and ammunition (25.4), manufacture of electrical equipment (27), manufacture of machinery and equipment n.c.a. (28), manufacture of motor vehicles, trailers and semi-trailers (29) and of other transport equipment (30), excluding manufacture of air and spacecraft and related machinery (30.3);
3. Medium-low, manufactures that belong to this class are manufacture of rubber and plastic products (22), manufacture of other non-metallic mineral products (23), manufacture of basic metals (24), manufacture of fabricated metal products, except machinery and equipment (25) excluding manufacture of weapons and ammunition (25.4), building of ships and boats (30.1), repair and installation of machinery and equipment (33);
4. Low technology, in this last category the sectors are manufacture of food products (10) and of beverages (11), manufacture of textiles (13), manufacture of wearing apparel (14), manufacture of leather and related products (15), Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and

[5] NACE code (*Nomenclature statistique des activités économiques dans la Communauté européenne)* refers to the classification of economic activities which is adopted by the European Union.

plaiting materials (16);Manufacture of paper and paper products (17), printing and reproduction of recorded media (18), manufacture of furniture (31) and other manufacturing (32) excluding Manufacture of medical and dental instruments and supplies (32.5).

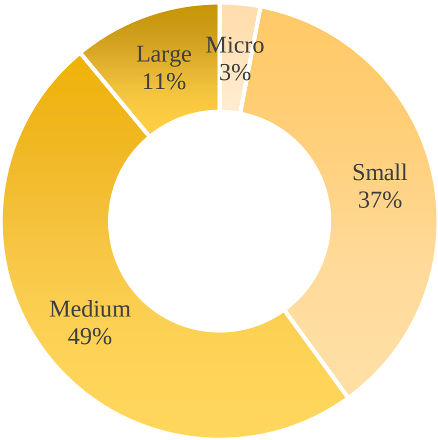
Graph 5 shows the distribution of the sample according to these four levels of technological intensity. The high technology is the class with less firms, only 25 out of 447, which is equal to 6%. 168 companies belong to medium-high technology class (37%), followed by medium-low technology class, which contains 144 companies (32%) and low technology, with 110 companies (25%).

Graph 5*: Technology intensity in the sample*



The last important characteristic to study in order to have a general overview of the sample is the dimension of analysed companies. This classification divides firms in four main groups based on the number of employees. Firms that have less than 10 employees are identified as micro-firms; firms whose number of employees range between 10 and 49 are referred to as small-firms; firms having more than 49 employees but less than 250 are medium-firms and those firms that register more than 250 employees are large. *Graph 6* gives a clear view of the type of companies in the sample by following size criteria to cluster them. The sample contains 13 micro- firms, 168 small-firms, 221 medium-firms and 49 large firms, for a total of 451 firms, which communicated in the survey their number of employees.

Graph 6: Size of companies in the sample



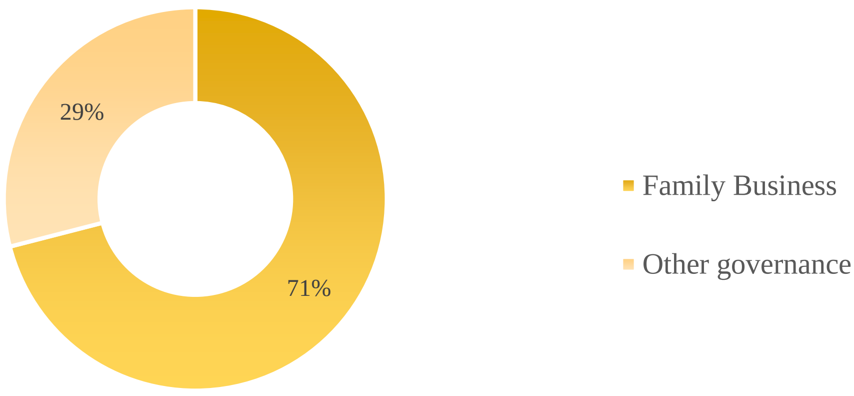
The Italian industrial framework is characterized by the presence of the so-called SME, hence small-medium size enterprises. In *Graph 6* the two groups composed of small and medium firms are the most numerous and the two combined percentages represent the 86% of the total manufacturing firms of the sample.

3.2.1. Organizational dimension and main characteristics of the sample

Once having the general description of the sample and its basic characteristics, other elements must be analysed in order to have a deeper understanding about the kind of organizations, which are analysed.

In the survey, the first section investigates the corporate management and one question asks whether the firm is a family business or not. A family business indicates an organization that is owned and managed by the members of a family. In Italy this type of governance is regularized by the article 230 bis of the Italian Civil Code. From the answers of 449 companies out of 454, the firms being family business are 317, whilst the others are only 132. Thereby, the percentage of family business in the sample is equal to 71% and the remaining percentage is 29%, as illustrated in *Graph 7*.

Graph 7: *Corporate governance*



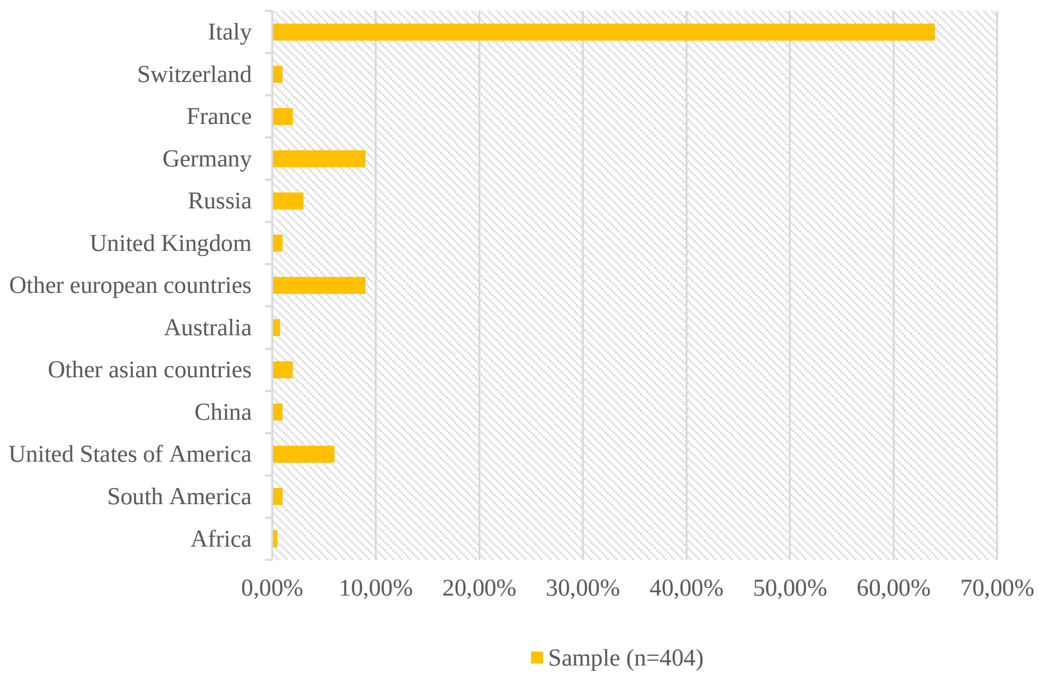
This high percentage of family business should not be surprising because the number of family businesses in Italy is one of the highest among European countries. According to "Osservatorio UAB"[6], in Italy companies with a turnover higher than 20 million euros are for 65% family businesses; this percentage is even higher for companies that have a turnover less than 20 million euros; in fact it is equal to 85% of the Italian total number.

Global Family Business Survey (GFBS)[7] 2018 underlies an important difference between the Italian family business and the global average, which is the opening to new markets. Italian family businesses show a big interest to internationalization. They want to grow and to look for new customers, by expanding and exporting in other countries, a process that has already started and it is taking place. This development can be noticed also in the sample, because most of the companies have the Italian market as main market but there is also good number of companies that succeed around the world. In *Graph 8*, the opening process is testified by those Italian companies that have their main market in other countries, even if the rate of the companies which operates better in Italy is still high, being equal to 64%.

---

[6] Osservatorio UAB has been founded in 2009 and it contains detailed and updated information about the ownership, management, economic and financial performance of Italian family businesses.
[7] Global Family Business Survey is carried out by the accounting firm "PwC" and it surveys nearly 3,000 family businesses across 53 territories.

__Graph 8__: Main markets of the sample



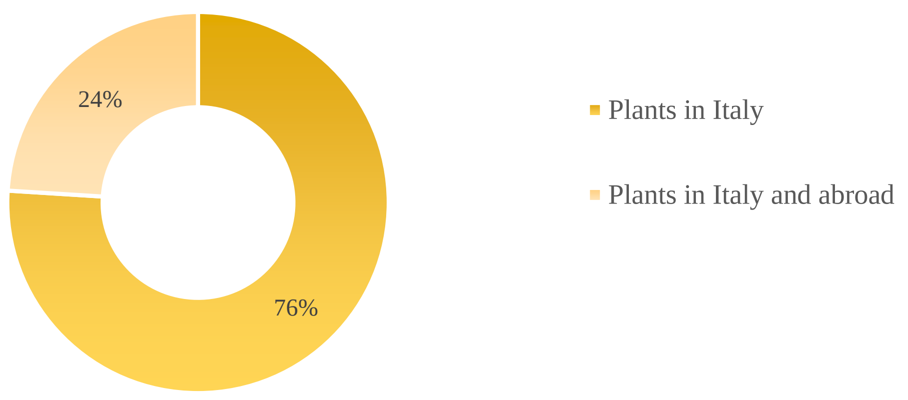
Moreover, the survey investigates also the percentage of revenues realized in the country where the main market is situated.

__Table 3__: Revenues in the main markets

Main market	Average revenues on total revenues
Italy	70%
Switzerland	56%
Germany	30%
Russia	24%
United Kingdom	20%
France	22%
Other European countries	36%
Australia	33%
China	33%
Other Asian countries	28%
South America	45%
United States of America	34%
Africa	13%

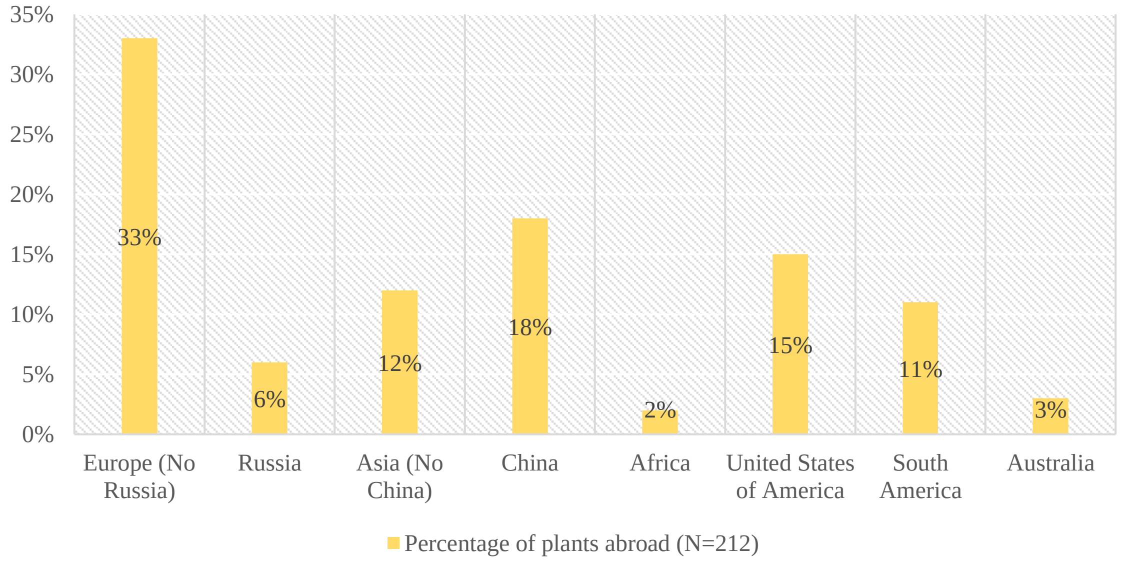
Beside Italy and Switzerland, the percentage of average revenues on total in other countries does not exceed 45%. In any case, internationalization process is a goal, which is not feasible overnight, but needs efforts and time. This explains the reason why the sample has a high percentage of firms that have Italian market as main market. Another consequence of this situation is the number of companies that have plants situated only in Italy and the number of companies that have plants situated also abroad. Among the 444 firms of the sample answering this question in the survey, only 105 firms have plants also in other countries; whereas, 339 firms have plants only in Italy. The gap can be clearly seen through the percentages of these results, which are illustrated in *Graph 9*.

***Graph 9**: Location of plants*



More specifically, *Graph 10* shows in which countries the factories of companies are situated, excluding Italy.

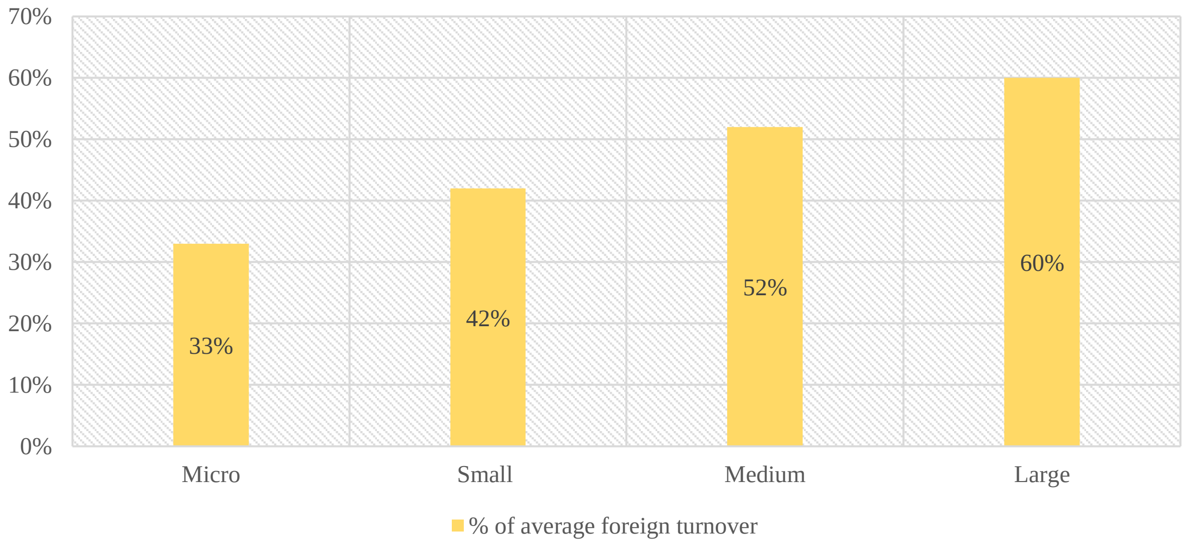
***Graph 10**: Distribution of plants in other countries*



Intuitively, among all other areas Europe is the area where most of plants are located (33%): there are 62 plants in Europe, excluding those in Russia, out of a total of 212 plants. Furthermore, also *Graph 8* shows that the main markets, beside Italy, are in Europe.

Even if companies that have plants abroad are just a limited number, the total number of firms, that have relationship abroad, is higher. This relationship is demonstrated by the high percentage of firms stating to have a foreign turnover. Out of 454 firms, 380 claim to have a foreign turnover, hence 84% of the sample. Of this percentage, for 184 companies (48%) foreign turnover represents more than 50% of total turnover. An interesting analysis is studying the presence of a relationship between size and foreign turnover. Therefore, a comparison that points out whether higher turnover is associated to larger companies or not is illustrated in *Graph 11*.

***Graph 11**: Average foreign turnover and firm size*



Graph 11 highlights a correlation between firm size and average foreign turnover, the larger is the company the highest is the foreign turnover on average. Micro and small companies have an average foreign turnover of less than 50%; whilst medium and large companies have an average foreign turnover higher than 50%.

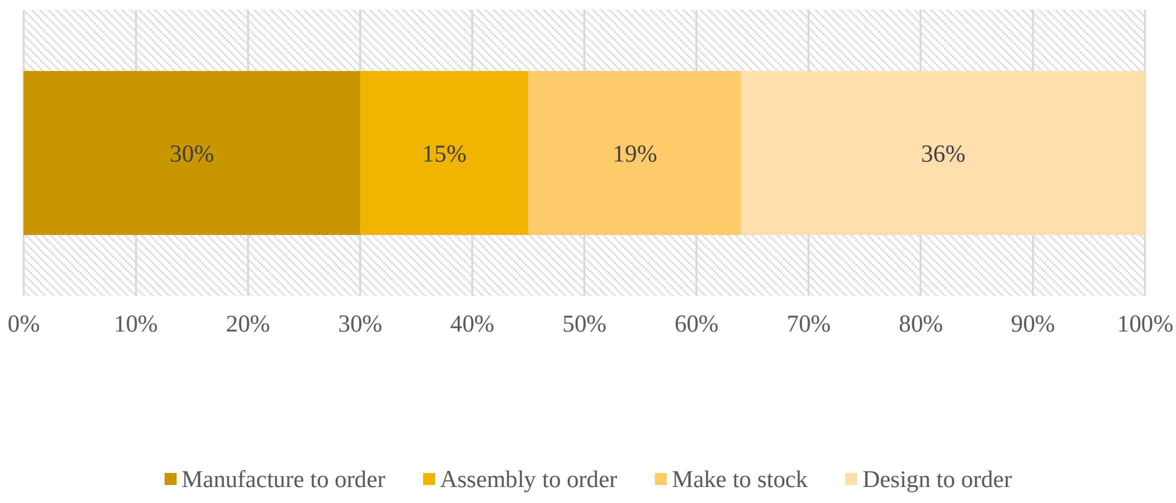
A further classification of the sample is the type of customer, to whom products of companies are sold. There are three main recipients: final customers, distributors and industrial companies. A company can sell to all these three categories, only to two or one of them or to other customers.

Table 4: *Average turnover for clients of the sample ((N=404)*

Type of customer	Average turnover
Final customers	9%
Distributors	32%
Industrial companies	54%
Others	5%

Table 4 describes the percentage of the average turnover associated to different kinds of customers. The highest percentage of average turnover is associated to industrial companies (54%), followed by distributors and then final customers. Types of customers can determinate and shape many processes and approaches of the firm, the survey investigates business production strategies by asking what the percentage of average turnover is in relation to design to order, manufacture to order, assembly to order and make to stock.

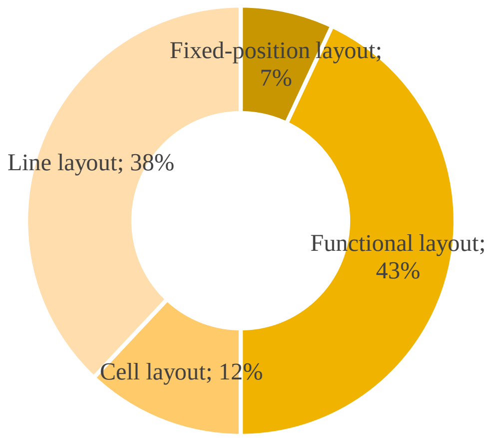
Graph 12: *Average turnover in relation to production strategy*



The largest percentage (36%) of average turnover is design to order, a manufacturing process that aims to satisfy each customer's need, by designing and assembling each part following consumer's order. The percentage (30%) related to manufacture to order, another approach according to which the production begins only once the order is received, is close to design to order. Assembly to order, which requires a customization to a certain extent, and make to stock, which relies on forecast to produce in advance, contribute to company's turnover for a 15% and 16%.

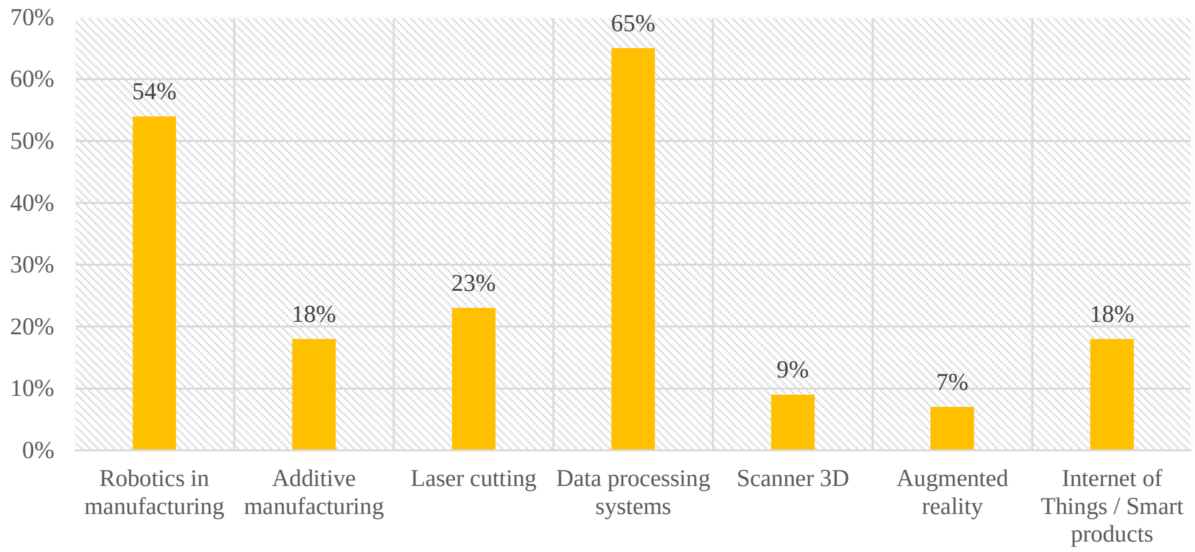
Moreover, the production strategy is also applied by choosing the productive layout, between fixed-position layout, functional layout, cell layout and line layout. The underneath logic of this decision should be to increase the responsiveness to customers' desires. The sample (N=438) contains results for each of these layouts. Most of companies prefers functional layout (43%), which is organized by functions and it involves large batches and transportation of goods from a function to another, this layout does not follow lean principles. The second most applied layout is line layout (38%), which is a production where workstations are situated along the production line.

Graph 13*: Productive layout*



The last part of the first section in the survey investigates the adoption of new technologies, belonging to industry 4.0, which aims to automation of traditional practices and all manufacturing components by exploiting smart technology. Companies of sample that are using technologies of industry 4.0 are 205 out of 300 (68%), hence an important percentage shows how much this technology is taking hold very rapidly even if it was introduced in Germany in 2011. Many European manufacturing firms embrace it because they can achieve better efficiency and costs savings (cf. Tay et al., 2018). The fourth industrial revolution consists in several new technologies, and each company can decide which and how many to implement. The percentage of technologies used in the sample is delineated in *Graph 14*. The most used technology is data processing systems (65%).

***Graph 14**: Percentages of industry 4.0 technologies*



Companies can have different combination of technologies; they can implement many technologies as much as they want. In *table 5*, there is the combination illustrating how often a specific technology is chosen at different levels of industry 4.0 adoption, resulting from the sample of 205 companies. None of these companies decides to adopt more than five technologies, in each combination data processing systems are the most used. The lower percentage of Augmented reality is probably due to the fact that this innovation is more recent.

***Table 5**: Combination of new technologies*

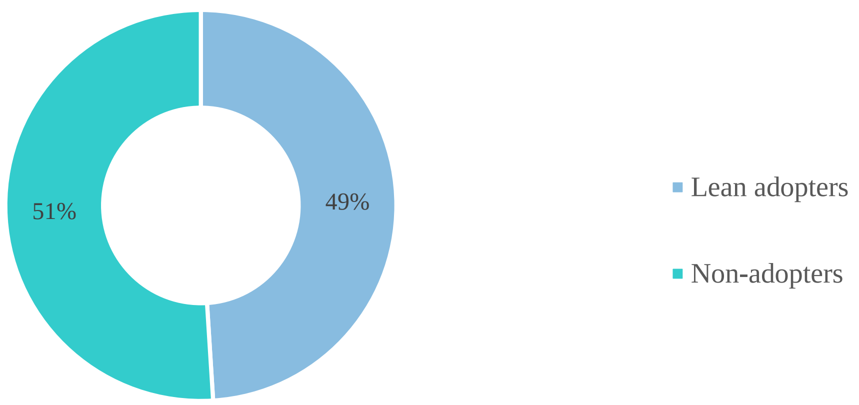
	Robotics in manufacturing	**Additive manufacturing**	**Laser cutting**	**Data processing system**	**Scanner 3D**	**Augmented Reality**	**Internet of things/ Smart products**
5 Technologies	5	7	5	7	7	5	2
4 Technologies	12	9	7	13	4	2	9
3 Technologies	18	5	8	18	3	1	7
2 Technologies	52	4	18	65	4	7	14
1 Technology	24	11	9	32	1	1	4

3.3 Lean companies of the sample

In the previous section, the purpose is analysing the sample by giving a general insight and by providing main characteristics without making distinctions between companies. The focus of this paragraph is, indeed, studying the sample by examining the comparison between lean adopters and non-adopters and, particularly, the behaviours and features of lean companies.

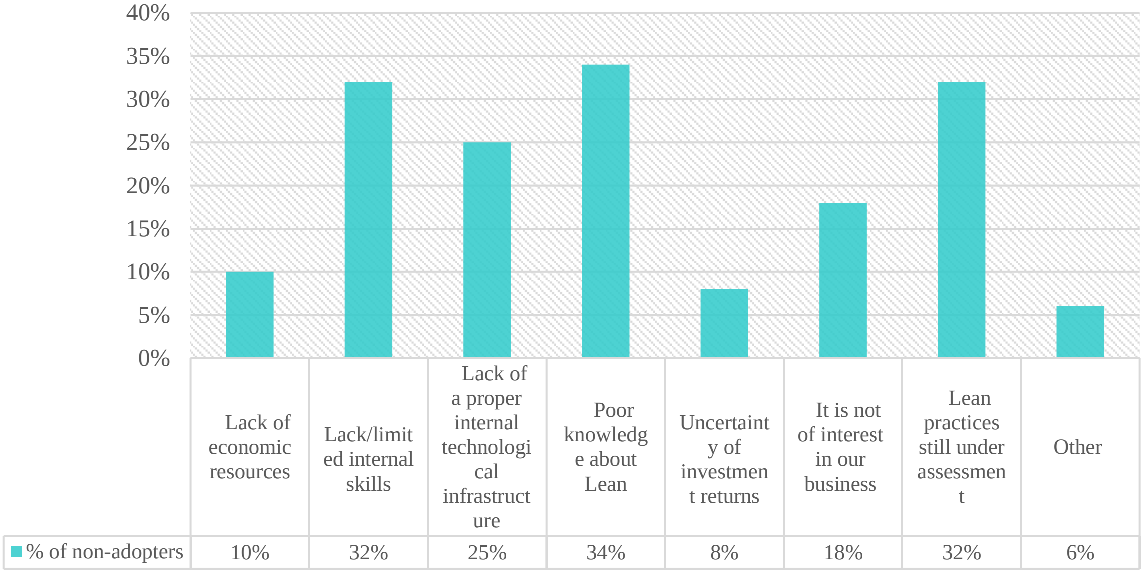
The second section of the survey is dedicated entirely to lean tools and techniques and the first basic question is directed at counting how many lean companies there are in the sample. Out of 454 companies, the lean companies are 221 (49%), whereas the non-lean firms are 233 (51%). Therefore, each cluster represents more or less the half of the sample.

Graph 15: *Lean adopters in the sample*



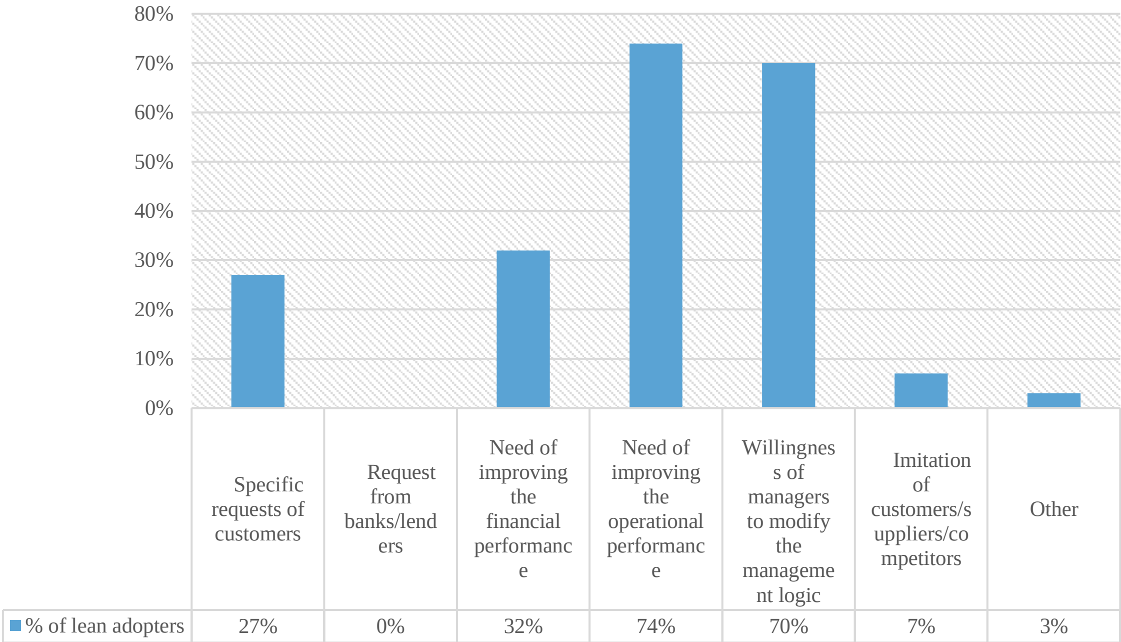
These two percentages in *Graph 15* are the results of strategical choices. In order to better understand the rationale behind different strategies, the investigation tries to explore the reasoning, which leads companies to take a specific decision in terms of lean implementation. Firstly, the survey focuses its attention on non-lean firms by asking them "*Why don't you adopt Lean Management practices?"*. From 91 answers it emerges that the most common reason is poor knowledge about lean (34%). Barker (1998) suggests that many managers resist change to lean manufacturing due to lack of skills and knowledge connected to lean manufacturing. Furthermore, lean implementation is blocked because some companies are still assessing lean (32%), they are facing the lack/limited internal skills (32%) or the lack of proper technological infrastructure (25%). All these listed reasons are internal obstacles, which hinder the adoption. This kind of reluctance towards lean implementation is understandable because it could lead to long-term damages if it is not carried out in the proper way, being an innovation involving each part of a firm, as illustrated in the first and second chapters. Nonetheless, a considerable number of firms answers that the reason why they do not adopt lean practices is the lack of interest for their business (18%), hence they are not even considering implementing lean tools. *Graph 16* shows this situation.

***Graph 16**: Reasons why firms decided not to adopt lean practices*



Once that the reasons not to adopt are clear, the survey investigates the reasons that lead lean companies to start implementing lean techniques. The main reasons, which the survey gathers on a sample of 143 companies, are: the need of improving operational performance (74%), which is the declared aim of lean management, the willingness to change management logic (70%) and the need of improving the financial and economic performance (32%). This critical issue is an indirect consequence of lean management, which could justify a lower percentage compared to the cited reasons, and it is the focus of this study.

***Graph 17:** Reasons why firms decided to adopt lean practices*

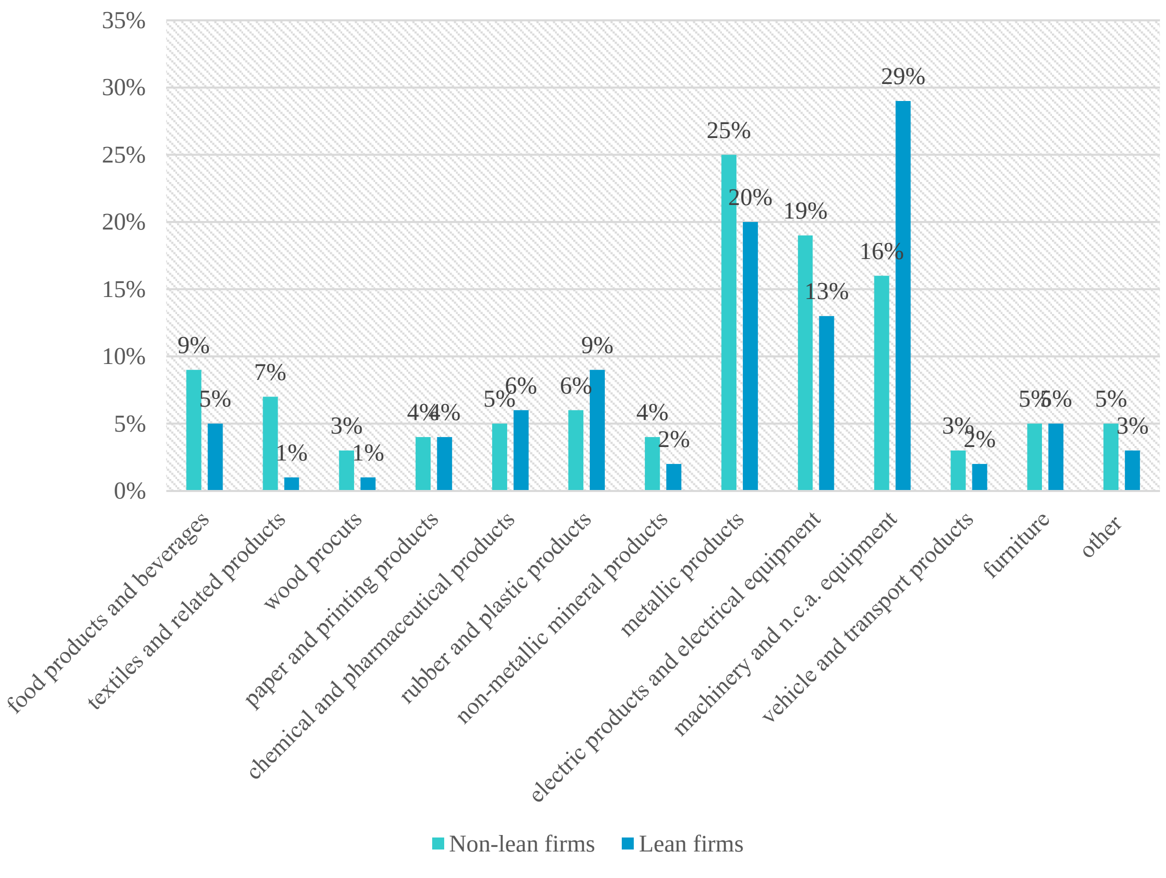


3.3.1. Comparison between lean firms and non-lean firms

Graph 15 shows that the sample is split into lean adopters and non-adopters and the quantity of firms in the two groups is similar, 221 lean firms and 233 non-lean firms. To better describe and understand the peculiarities of lean companies, it could be useful to compare them to companies, which do not implement lean tools.

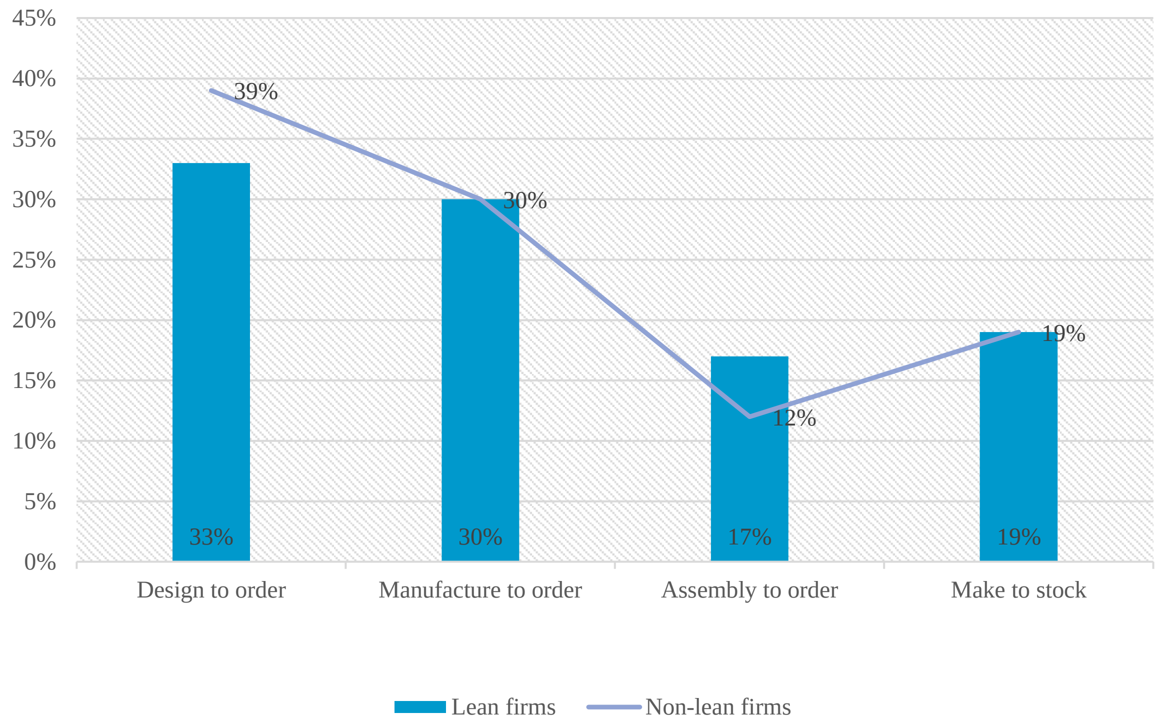
The first area to detect is the industry, in which lean is more used. In *Graph 18*, the manufacturing sectors, following ATECO classification, are illustrated with the percentages of lean organizations and of non-lean organizations. The comparison does not underlie a relevant difference between the two clusters. Specifically, the highest percentage (29%) of lean companies is related to ATECO 28, thus sector of machinery and n.c.a. equipment; whilst non-lean firms are more prevalent in metallic production, ATECO 24 and 25.

Graph 18: *Industry distribution between lean adopters and non-adopters*



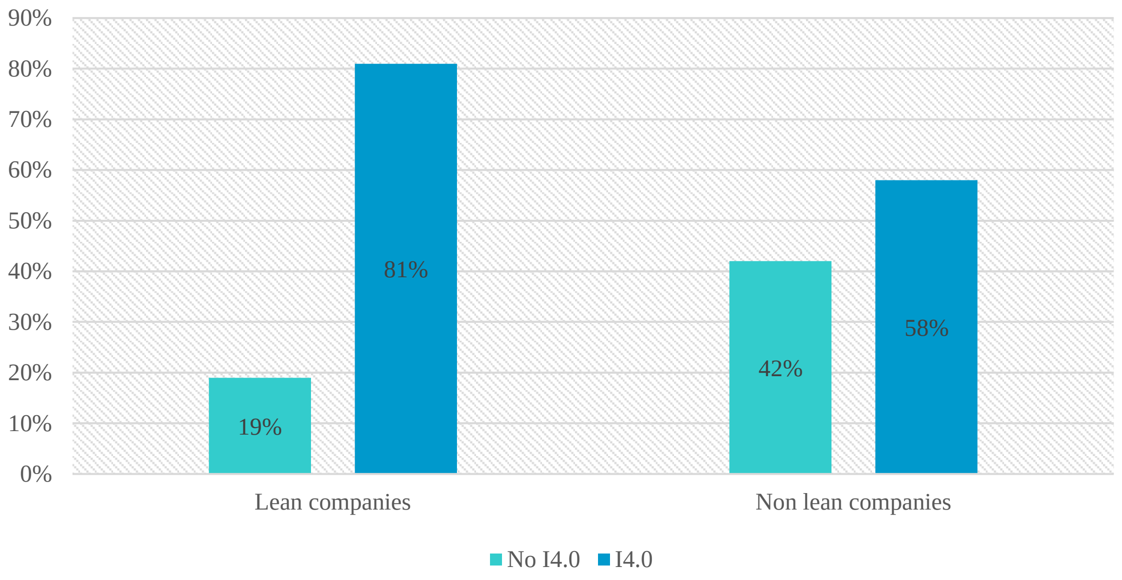
A relevant decision for lean companies is the production strategy to apply. In *Graph 12*, the percentages of average turnover are showed for each production strategy. In *Graph 19*, these percentages are divided in relation to the nature of companies. The comparison does not point out relevant differences between companies, which implement lean production, and companies, which do not.

***Graph 19**: Average turnover of production strategy in lean and non-lean firms*



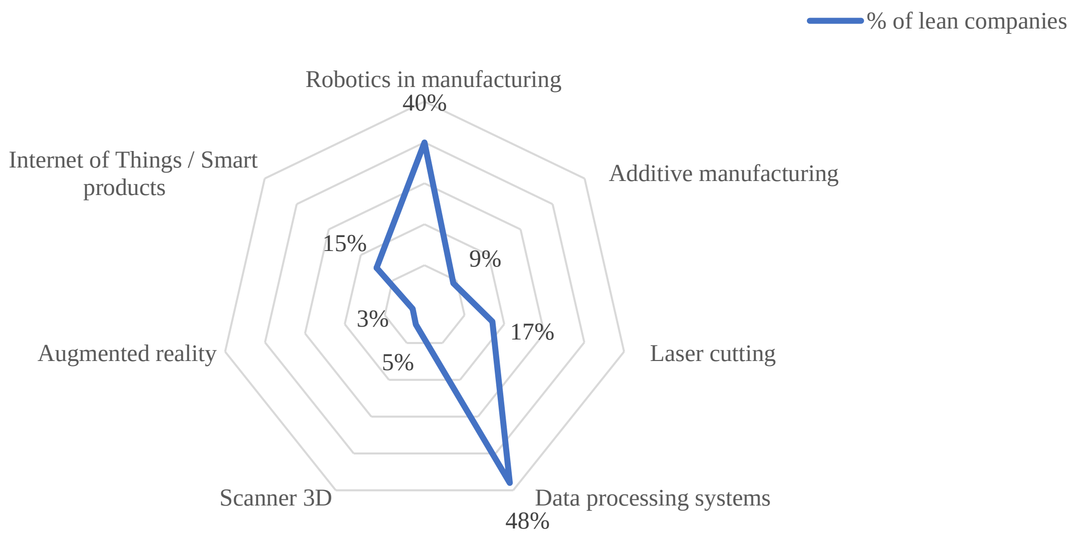
The relationship between industry 4.0 and lean techniques is widely investigated and it is declared that industry 4.0 leads to enhancement of lean production. Kolberg and Zühlke coined the term "Lean Automation" to describe the complementary integration between the two concepts "in order to combine benefits from both domains". There are many smart solutions, and one of them is the so-called flexible Kanban production scheduling, which allows to digitalize the Kanban system. The logistics and lean management find positive solutions because "I4.0 integration provides real-time information flow, flexibility and optimized value-creation" (Pereira et al, 2019). Moreover, lean organizations can exploit real-time database, cloud computing, virtual and augmented reality and many other smart solutions that enable waste reduction and more efficiency. *Graph 20* shows the diffusion of tool and techniques in lean companies compared to the diffusion of non-lean companies. The percentage of firms, which adopt tools and techniques both of lean and of industry 4.0, is equal to 81%, thus 115 out of 142 firms; whilst the percentage of non-lean firms adopting industry 4.0 is equal to 58%, thus 95 out of 163 firms. Hence, the deployment of industry 4.0 in non-lean firms is significantly lower than the deployment in lean firms.

Graph 20: *Exploitation of Industry 4.0*



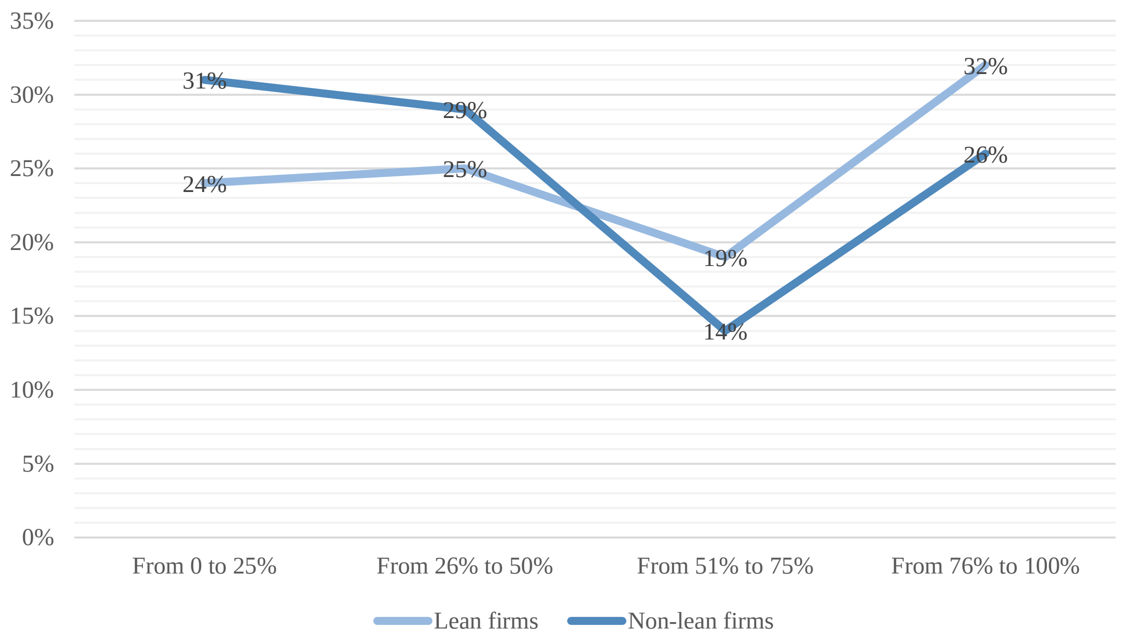
More deeply, analysing the answers of the survey, it can be provided also a spectrum of the technologies, which are most common among lean companies. According to *Graph 21*, the most applied technology in lean companies is data processing system (48%), followed by robotics in manufacturing (40%).

Graph 21: *Industry 4.0 technologies in lean companies*



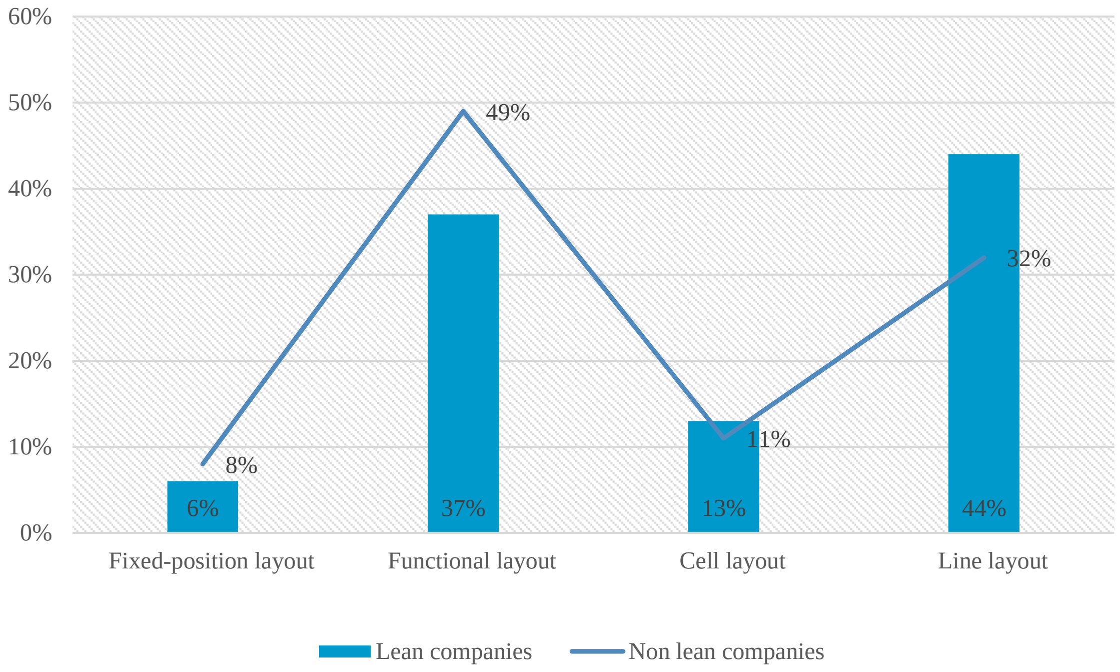
The introduction of new and smart technologies aims to reach better operating performance and continuous improvements. Another practice with similar purpose is job rotation. Job rotation is a type of training, that implies the movement of employees from one department or from one position to a different one in order to develop skills and know-how of every area of the company (cf. Oparanma et al., 2015). Therefore, workers can improve not only their problem-solving abilities but also their vision of operational process. Job rotation is valued positively by lean adopters: “lean manufacturing advocates rotating operators between different jobs so that the workforce becomes flexible enough to respond to any unexpected labour shortages or demand fluctuation. Operators will increase their knowledge and feel focused, involved and motivated” (Allwood and Lee, 2004). Nonetheless, there are conditions to succeed in job rotation according to McCreery and Krajewski (1999), and job rotation is less effective when the tasks are complex. In *Graph 22*, the results of each company type - lean and non-lean - are divided into four groups according to percentages of blue collars who rotate. In 62 out of 195 lean companies, more than 75% of employees is able to work in more than one workstation. The range 76-100% contains the largest number of lean companies; whereas the largest number of non-lean companies is in the range 0-25%. Hence, in 67 out of 215 non-lean companies, less than 26% of employees are able to work in many workstations.

Graph 22*: Job rotation in lean and non-lean companies*



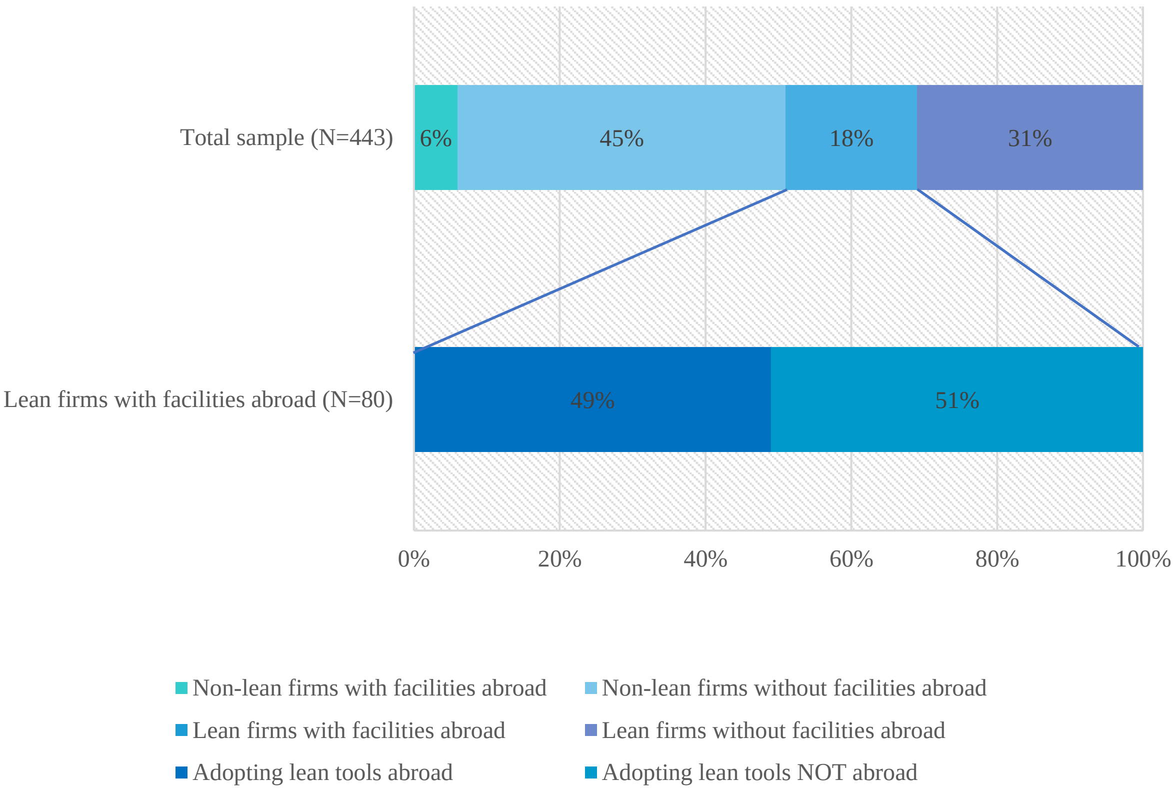
In relation to the implementation of job rotation, the most appropriate productive layout for lean companies is cellular manufacturing because employees are multi-skilled and dedicate their abilities to many productions processes. “Once implemented, cellular manufacturing has been said to reliably create massive gains in productivity and quality while simultaneously reducing the amount of inventory, space and lead time required to create a product. It is for this reason that the one-piece-flow cell has been called "the ultimate in lean production” (Jayakumar et al., 2018). However, *Graph 23* shows another scenario for 219 lean companies of the sample. Most companies (44%) uses fixed line layout, followed by functional layout (37%); whereas for 108 non-lean adopters out of 219, the favourite layout is functional layout (49%). Cellular layout is exploited only by 28 lean companies, thus it occupies only 13% of total. This layout has a really low percentage considering that it is supposed to be the most suitable for lean production.

***Graph 23**: Production layouts of lean companies*



Finally, it is interesting to analyse whether the companies, which apply lean practices, have facilities abroad and whether these foreign facilities implement lean methods or not. *Graph 24* analyses the overall situation of plants situated in other countries between lean adopters and non-adopter. Companies having foreign facilities are the minority in the sample and they are 105 out of 443. More specifically this cluster of 105 firms is composed of 80 lean firms out of 443 (18%) and of 25 non-lean firms (6%). A further classification can be done among the 80 lean firms owning facilities abroad: those firms that implement lean practices only in their Italian plants and those firms that implement lean practices also in their foreign plants. The second horizontal bar of the graph below analyses this further categorization by delineating the percentage distribution of lean companies applying lean techniques abroad, which is equal to 49%, and of lean companies not applying lean techniques abroad, which is equal to 51%. Therefore, the number of companies – 41 out of 80- which decide to implement lean production only in Italy is substantial, but it is not startling considering that lean practices are relatively new in many companies of the sample.

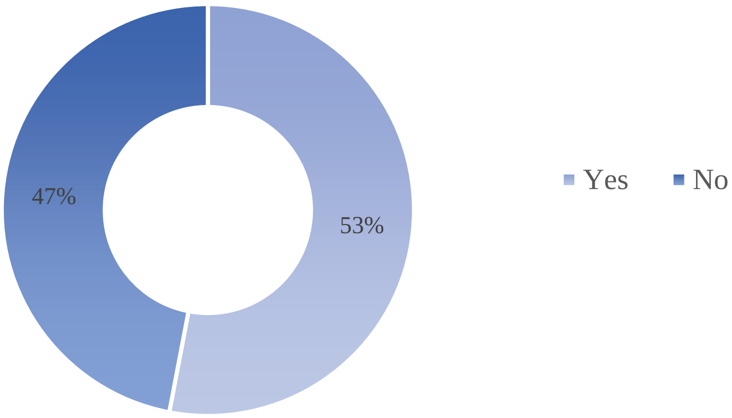
***Graph 24**: Comparison of foreign facilities between lean adopters and non-adopters and implementation of lean tools abroad*



3.3.2. Involvement of people in lean firms

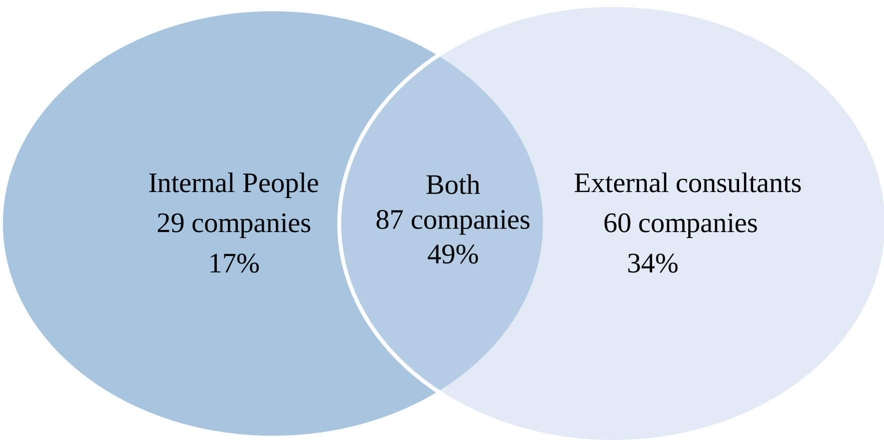
The further step is inspecting the role and the involvement of employees and managers in lean organizations. The structure of lean companies could include the presence of people who are dedicated exclusively to the implementation of lean techniques, and people who are external experts and they must help the lean adoption. The analysis on the first group of workers set forth that more than half (53%) of lean companies has people involved completely in lean implementation, hence 116 out of 217 companies, as illustrated in *Graph 25*.

Graph 25*: Are there people within your company who are exclusively involved in the implementation of Lean techniques?*



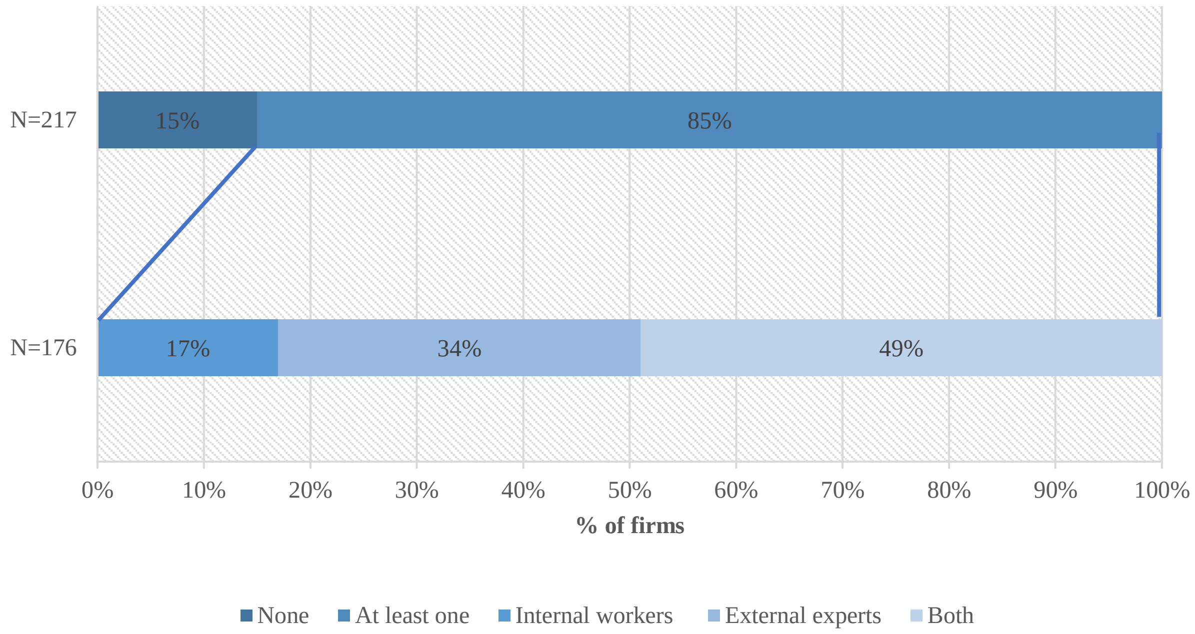
The percentage of organizations hiring external consultants is even higher than the percentage of companies hiring only internal people. 176 companies state to have internal people, external people or both. 60 companies declare to have external experts for the implementation of lean techniques (34%) and 87 firms implement both these two professional figures (49%). This decision could overcome the problem of lack of internal skills, that is one of the main obstacles to implementation, because companies would introduce in the organizational structure high-skilled people, and probably this is the reason why so many companies rely on this solution. *Figure 4* exhibits the numbers and the percentages of companies implement only one of these two solutions and of those that implement both.

Figure 4*: Combination of internal people and external consultants*



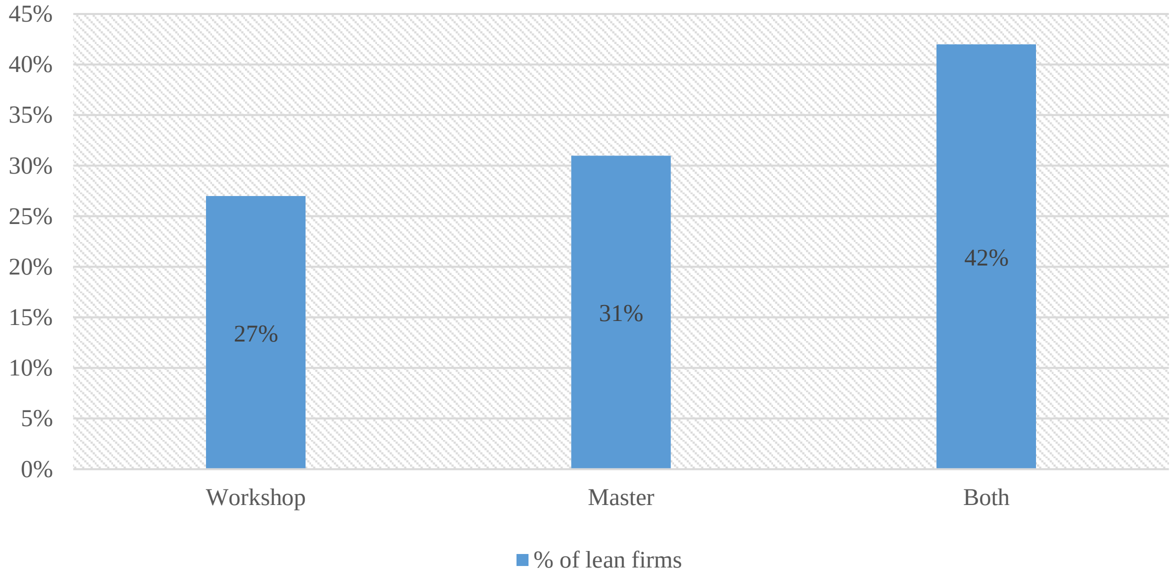
Hence, most of the firms think that it is more convenient to have both people from outside with high experience that could help in the first stage of implementation and people inside the company that could develop internal knowledge and skills. This configuration is reported in *Graph 26*.

__Graph 26__: Workers dedicated to lean adoption



The acquisition of know-how and skills to pursue lean transformation is fundamental for successful and correct lean implementation. In order to develop internal knowledge, learning and training are critical elements and they are directly connected to lean maturity, as described in paragraph 2.4. “Resistance from employees may be due to the reasons of low commitment and inadequate. However, this obstacle can be overcome through more education and training performed by these workers […]. Appropriate training on the lean concept, basic principles, and reasons can give a greater level of lean understanding, encourage motivation and innovation, and polish the employee’s attitudes” (Nordin et al., 2012). Lean firms can adopt different types of training, the survey summarizes them into two kinds of training, in which lean companies invest: (1) master, hence training course for employees, executives and/or managers and (2) workshop, training course for workers. 175 companies are part of the sample: 54 invest in master (31%), 47 invest in workshop (27%) and 74 decide to invest in both training (42%), as described in *Graph 27*. The highest percentage identifies those companies that have both in order to make people aware if the organizational change at each hierarchical level. In this way, everyone would lead the firm towards a common goal.

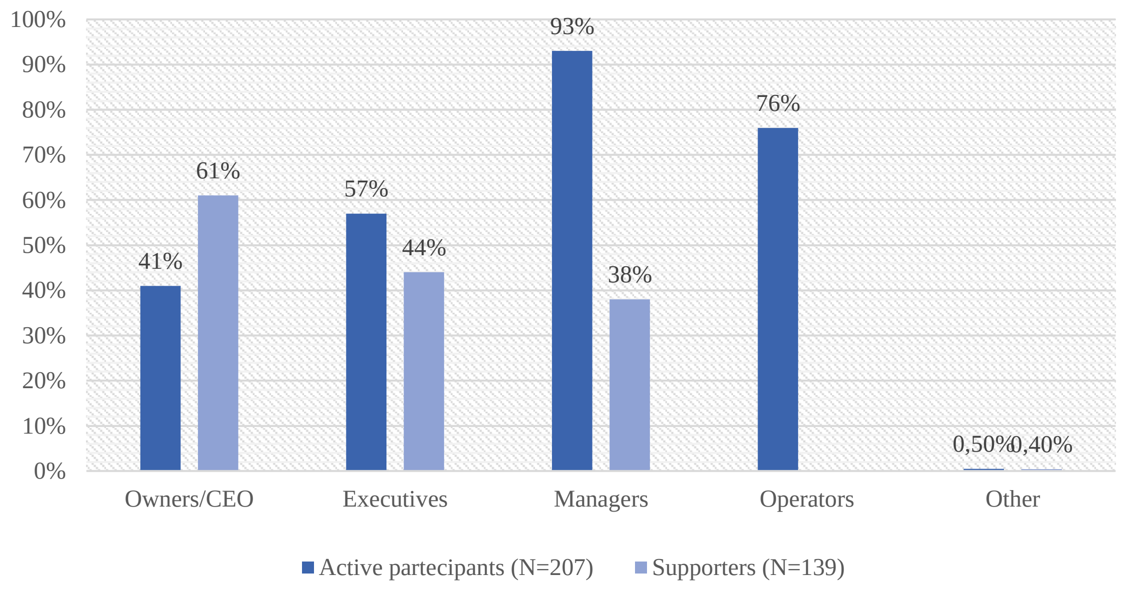
***Graph 27**: Kind of training lean firms invested in*



More than once, it is emphasized the importance of each person's involvement in lean transformation in order to facilitate organizational change and to reduce the scepticism. In relation to this topic, the survey investigates who are the main supporters of lean techniques and at what extent different hierarchical levels participate actively in lean transformation. The main supporters are the CEO (61%) and/or the executives (44%) in most of the cases, thus in this kind of organizational change many companies have a top-down approach. This method is normally used when the organizational change has a serious strategical impact on the company it entails a big transformation from the initial firm structure and form. Rayn et al. (2008) say in a very effective statement that the more radical the change, the more important is the involvement of most senior people in the organization, and this is the case of lean change. Therefore, executives have the task of planning and leading the change, middle managers must coordinate and supervise internal management of change, whereas non-managerial workers do not take part in the decision making but they are essential for lean achievement (cf. Rayn et al., 2008). The configuration of people involved actively in lean transformation deviates from the configuration of people supporting lean practices, because CEO, owners (41%) and executives (57%) have less weight in this phase, but managers (93%) and operators (76%) are the protagonists of actively implement lean tools and techniques.

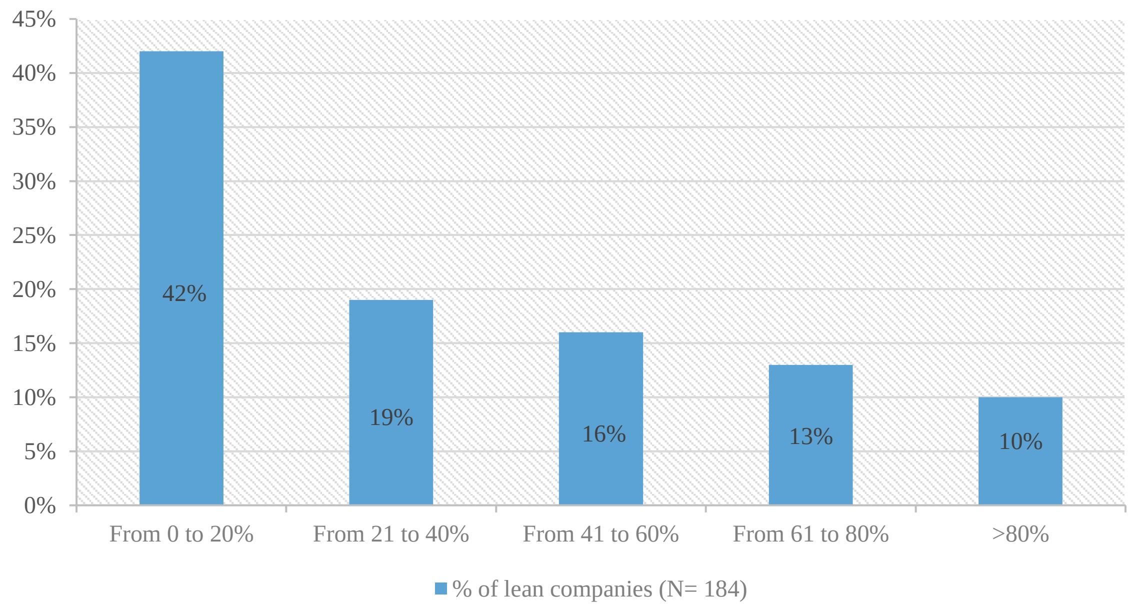
Graph 28 points out the different distributions of the two analysis, which emerge from the survey.

Graph 28*: Supporters and active participants in lean transformation*



Even if people at higher hierarchical levels have the power to take decisions, the engagement of employees in lean projects is also important, and according to many studies a profitable lean implementation depends on the involvement of employees (cf. Marin-Garcia & Bonavia, 2015). *Graph 29* makes clear that companies struggle to have a good percentage of employees involved in lean projects. When the number of involved employees increases, the number of firms decreases and this inverse proportion means that those lean organizations that reached a good degree of involvement, are few.

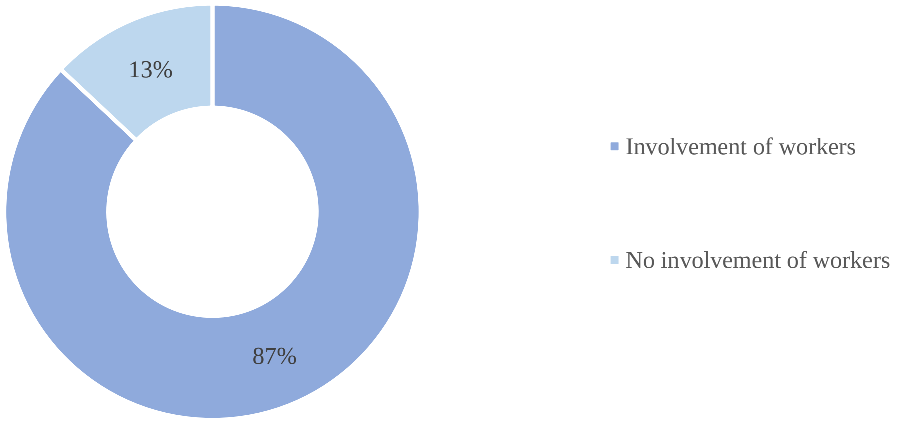
Graph 29*: Employees involvement rates in lean projects*



The *Graph 29* shows the results of the survey divided into five main groups according to the declared percentage of involvement. The first cluster contains the most numerous group of companies (42%) and identifies companies whose involvement rate ranges between 0% and 20%. Furthermore, it is alarming that, within this group, 2,5% of companies states to have an involvement equal to 0%. The second range is between 21% and 40% and it represents 19% of companies, followed by the range 41-60%, which results to be 16% of the total. Finally, the last two groups show the results of the range 61-80% and of the range 81-100%, which respectively include 13% and 10% of firms. The higher is the involvement rate, the lower is the percentage of lean companies.

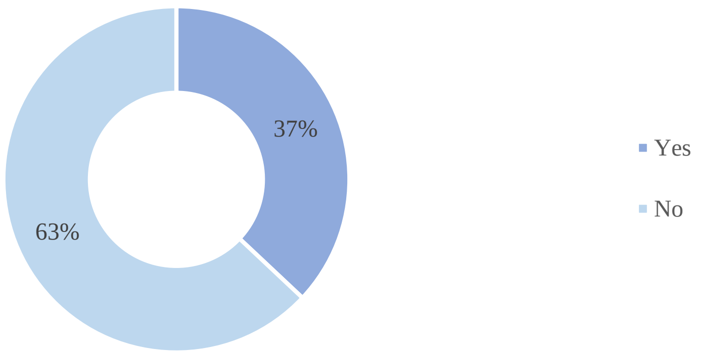
The engagement of workers is strategic also because people at different level with distinct tasks can have another view of production process and they could note defective functioning and propose new ideas or solutions, which otherwise would not be taken into consideration. This explains the high percentage (87%), illustrated in *Graph 30*, of workers involved in improvement process.

Graph 30: *Workers' involvement in improvement process*



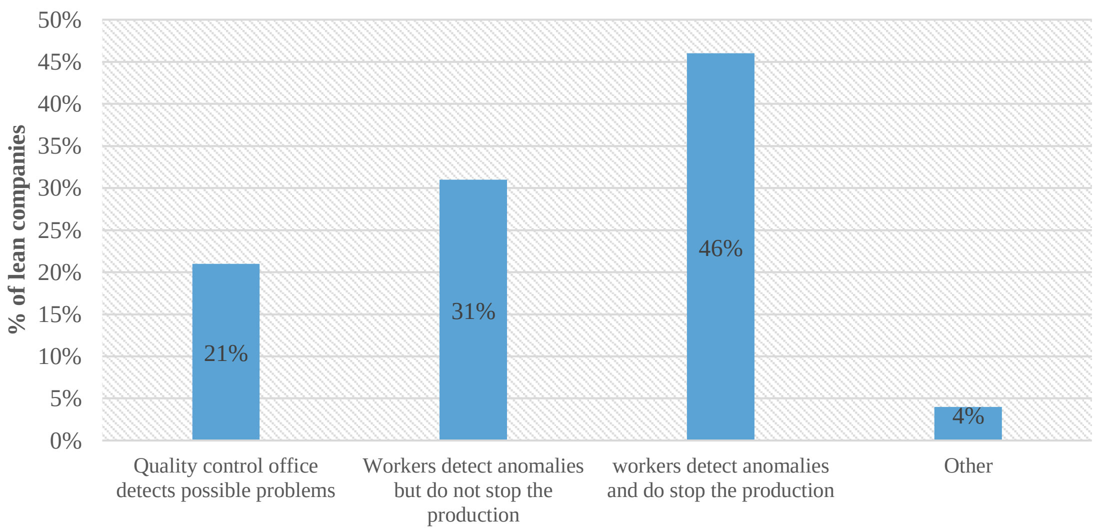
In addition, to exploit the potential of workforce, another useful tool is suggestion system, that has "the capability of being all inclusive by being able to focus on capturing ideas from all workers, and not just ideas from identified few smart workers" (Arif et al., 2010). The purposes of suggestion system are several, for example better utilization of workers, strengthening of workforce morale and loyalty, better communication and decision making, increasing value added activity and decreasing nonvalue added activity. All these benefits can be summarized in a single goal: constant improvement (cf. Chapados et al.). Lean production wants to maximize efficiency by continuous improvements, nonetheless, in the sample of 205 lean companies only 76 lean firms use suggestion systems (37%), as reported in *Graph 31*.

***Graph 31**: "Do you use any suggestion system within your company?"*



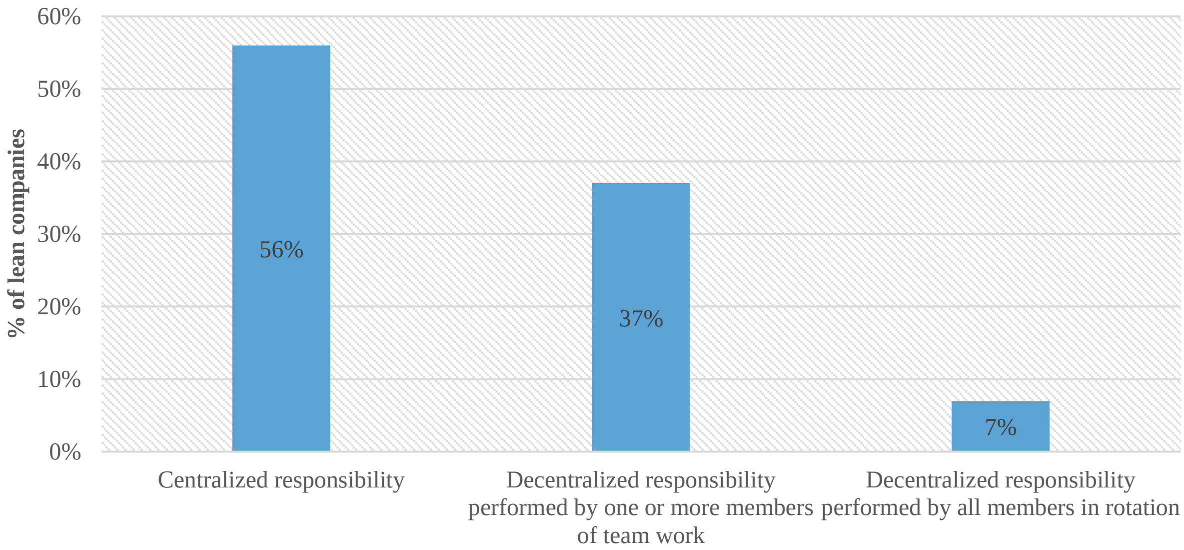
The employee suggestion systems can be used to detect not only new creative idea but also any anomalies or problems. Spotting as soon as possible malfunctions or technical issues is vital for the correct operation of the whole system, lean companies can implement different approaches to solve these problems. The survey investigates who is responsible to spot these anomalies and how they are supposed to behave, thus whether they can stop the production or not. As expected, workers have an important role in this task working directly in the manufacturing mechanism. In *Graph 32*, the most used approach (77%) is delegating to workers the responsibility of detecting any issues. This method can be further split into two groups depending on the allowance of stopping the production. The percentage of companies, which picks workers to detect possible product or processes anomalies and to stop the production process in order to implement the needed corrective actions, is equal to 46%; whilst the percentage of companies, which pick workers as supervisor without allowance of stopping the production, is equal 31%. Another approach to implement either alternatively or simultaneously is relying on the quality control office to detect defective products and anomalies in the production process (21%).

***Graph 32**: Approach to detect anomalies and problems*



Eventually, lean companies must decide whether to apply a centralization or decentralization approach. “Centralization means one focus of control” (Limoncelli & Hogan, 2002), thus the decision-making power and responsibility are in the hands of few. Decisions are made by top managers, people at lower hierarchical level implement their decisions. On the contrary, decentralization means that control tasks are entrusted to many in the company. In lean companies, the level of decentralization is supposed to be wide because it increases flexibility and responsiveness, moreover, “it is postulated that the basis of organization of work processes in companies implementing lean management is a team work. A consequence of working in teams is decentralization and power transfer to teams, which are largely autonomous, and employees have the ability to self-control” (Faron, 2012). Hence, team work is largely used in lean production and it can divide the decentralization in two types: supervision and control activities are performed directly within the teamwork either by one or more members of it or by all members in rotation. In the sample of 202 lean companies, the rate firms adopting the first type of decentralization is equal to 37%, whilst the rate of adoption of the second type is equal to 7%. Nonetheless, the highest percentage (56%) is referred to lean firms with centralized responsibility, where supervision and control activities are performed by the department head.

Graph 33: *Different approaches for allocation of supervision and control tasks*



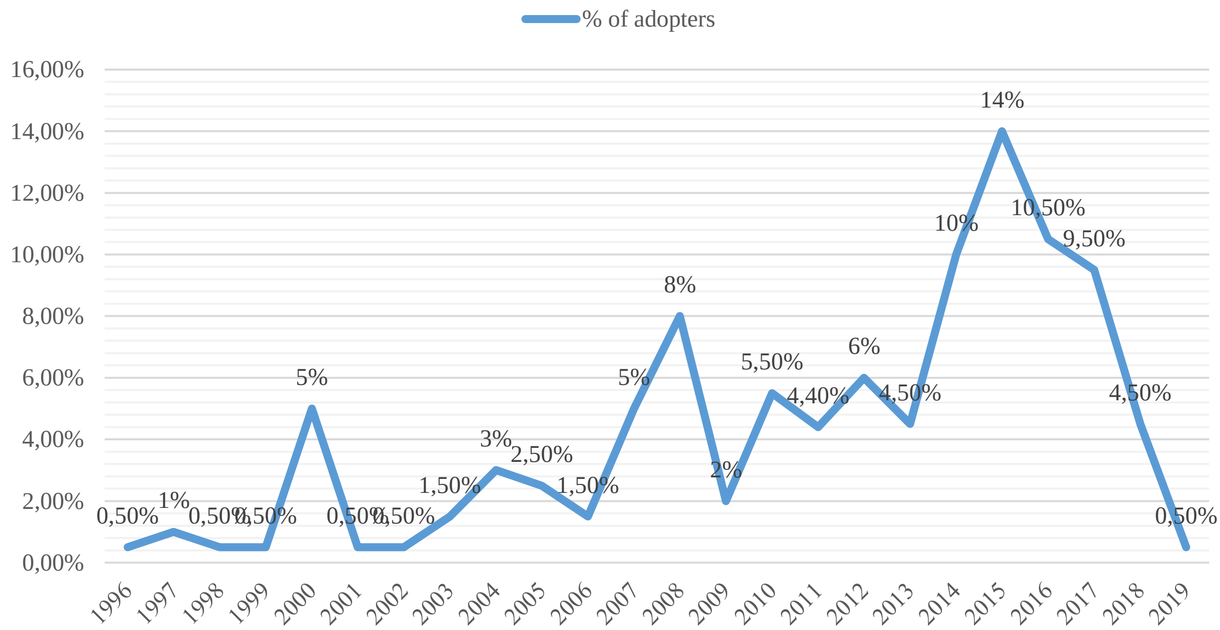
3.4. Lean maturity and lean intensity

After having described the main features of lean companies in the sample, it is necessary to deepen the role of time, thus the maturity of lean organization, in order to better introduce the statistical analysis.

3.4.1. Lean maturity in the sample

A fundamental element for this study is the lean maturity, the survey contributes to provide information about lean maturity by asking "*In which year did you start implementing Lean techniques*". 202 companies disclose how old they are, thus which level of maturity they have reached. *Graph 34* reports the numbers – expressed in percentages - of new adopters between a range of 24 years, from 1996 to 2019, and it delineates a positive trend until 2015; afterwards the number of new adopters pro year decreases heavily. In this part of the description, the trend gives a general idea of lean maturity and of the "age" of lean companies but this topic is analyzed more extensively later in this paper.

Graph 34: *% of new lean adopters pro year*



From the year of implementation, the maturity of lean companies can be easily deducted, which is calculated by subtracting from the current year -2020- the year of lean adoption. Most of the lean companies in the sample are relatively young in terms of lean maturity. More than the half of the firms has less than 10 years of experience in lean production and only few firms have more than 20 years of maturity.

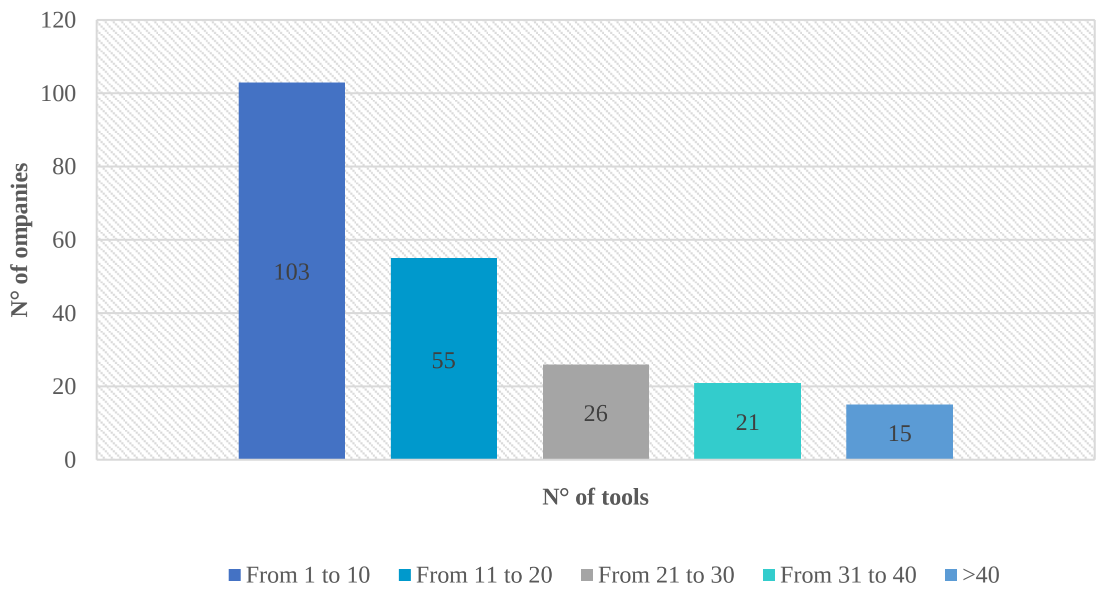
To study whether lean companies have positive financial results over time, in the statistical analysis the different years of maturity are clustered. Nonetheless, levels of lean maturity used in the empirical analysis are framed between 2009 and 2018 because information regarding financial performances is available until 2018.

3.4.2. Degree of leanness in the sample

Organizations approaching lean management may not have the same goals and priorities. Therefore, the set of lean practices will be different among companies considering that lean implementation involves a broad number of tools and techniques. By leanness is meant all these tools and techniques, which are used to promote lean (cf. Bayou et al., 2008). Specifically, degree of leanness is the extent to which companies implement a portfolio of lean procedures, thus high degree of leanness implies adoption of a large number of lean techniques (Galeazzo, 2019).

In the sample, lean companies do not adopt identical lean bundles but have different combinations. First, *Graph 36* illustrates the numbers of firms according to how many lean techniques they carry out. The cluster from 1 to 10 techniques contains a big number of companies, 103 out of 221 (46%). Among these firms, 48 have decided to implement less than five practices. Nevertheless, this result is not surprising because lean adoption took place recently for many firms, as described in the previous paragraph.

Graph 35*: Number of lean tools in the sample*



Moreover, in order to provide a better picture of lean intensity, the survey analyses which the implemented tools are and in which business area they are applied. *Table 6* shows the combination of nine business areas with sixteen lean practices among 221 lean companies of the sample. The business area where lean is more exploited is production, where many tools are efficient and suitable, and warehouse, because many lean practices are targeted to a functional use of this area in order to avoid waste. The lean tool more used is 5s method, followed by the pull/Kanban approach and visual stream mapping (VSM). This latter technique is described as “a graphical way of presenting material and information flow in the production system. Map shows all the tasks undertaken in the process, from the purchase of raw materials and ending with the delivery of finished products to the customer. This analysis allows the identification of all kinds of waste and orientation for further action in order to eliminate them” (Rewers et al., 2016). On the other hand, the areas, where lean production is not performed by many companies, are sales, technical office, administration and control and IT; especially when these tools are combined with total productive maintenance, Simultaneous engineering, Hejunka, Six Sigma, Single Minute Exchange Die (SMED) and Andon.

***Table 6**: Lean tools that the companies adopt and in which areas*

	Production	**Warehouse**	**Internal logistic**	**Quality control**	**Purchasing**	**Sales**	**Technical office**	**Administration and Control**	**IT**
Visual Stream Mapping	54%	27%	28%	14%	14%	9%	12%	6%	5%
5S	63%	39%	32%	22%	10%	8%	13%	7%	7%
A3	22%	13%	10%	14%	8%	6%	8%	4%	3%
Pull/Kanban	54%	47%	30%	5%	21%	3%	3%	0%	0%
Flow layout	52%	18%	22%	6%	4%	2%	3%	2%	1%
Visual management	47%	28%	24%	22%	9%	11%	17%	7%	5%
Standardized work	43%	19%	18%	18%	10%	10%	13%	7%	5%
Kaizen	45%	21%	21%	12%	11%	8%	10%	6%	4%
Poka Yoke	34%	11%	9%	10%	5%	3%	7%	3%	4%
Total Productive Maintenance	29%	4%	4%	3%	1%	0%	1%	0%	1%
Suggestion system	36%	19%	13%	13%	10%	10%	11%	7%	8%
Simultaneous engineering	8%	4%	0%	3%	3%	3%	8%	0%	1%
Hejunka	25%	5%	2%	1%	3%	0%	1%	0%	0%
Six Sigma	14%	4%	5%	9%	2%	0%	2%	0%	0%
SMED	31%	2%	1%	0%	1%	0%	0%	2%	0%
Andon	16%	3%	4%	4%	1%	1%	0%	2%	1%

CHAPTER 4: STATISTICAL ANALYSIS

4.1. Panel data

Once that the sample has been described in depth and the characteristics of companies have been illustrated, we can concentrate on the statistical approach in order to investigate the hypothesis that this paper aims to validate. As already exposed in *Chapter 2*, many authors doubt about the financial benefits of lean adoption. To contribute in this research, the investigation focuses on the role of maturity, thus of time. The data in the sample are collected over a vast period of time – more than ten years- by providing valuable information of different nature and different usefulness. Therefore, this plenty of information allows to exploit the longitudinal aspect of the sample, especially of the lean companies of the sample (49%). Indeed, the research is an analysis of *panel data (or longitudinal data) set*, which "consists of a time series for each cross-sectional member in the data set. […] The key feature of panel data that distinguishes them from a pooled cross section is that the same cross-sectional units are followed over a given time period" (Woolridge, 2006). In order to have panel data of the sample, observations of the same companies must be collected across time. Therefore, this set of data is multi-dimensional, including both the cross-sectional dimension and the time series dimension. Cross-sectional dimension refers to the data collection of a group of subjects at one point in time; whereas time series dimension refers to observations collected at regular spaced time intervals (cf. Deaton, 1985). One of the advantages of using panel data is the improvement of the efficiency of econometric models due to less multicollinearity and to higher degree of freedom. Furthermore, panel data analysis better captures complexity, which consists in testing more complicate hypothesis and better dealing with the effect of omitted variables (cf. Hsiao, 1985).

It is useful to remind and to keep in mind the hypothesis that this analysis aims to test:

Lean adoption has a positive economic and financial impact over time.

This hypothesis could be tested in different ways but it is concluded that the most suitable path to take it is through panel data regressions, which take into consideration various components and exploit longitudinal data.

The sample includes data for 454 Italian manufacturing companies - cross-sectional dimension, collecting economic and financial measures over a period of time of several years -time series dimension-. The purpose of the analysis is understanding if over time economic and financial performances of companies are influenced by the implementation of lean practices, whether this impact is positive and whether it changes as lean maturity increases. Therefore, the focus of the statistical analysis is on those companies that implement or do not implement lean tools and techniques, by studying different levels of lean experience and by considering the decade 2009-2018 as timeframe.

4.2. Components of regression models

In this case, the regression analysis must estimate the causal relationship between independent variables and dependent variables, which are the two main elements of any regression model. Being panel data, the variables considered for this research are also expressed in terms of span of time, considered for this research. Beside independent and dependent variables, also control variables are relevant components of the analysis.

4.2.1. The dependent variables: financial indexes

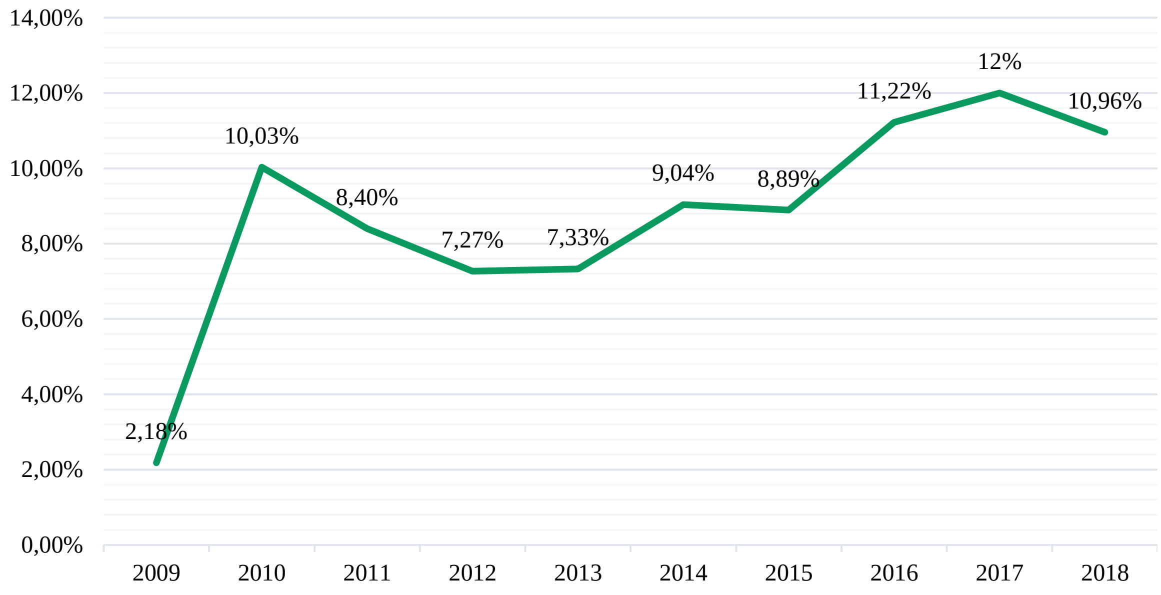
Dependent variables are the variables that are explained in the regression model and their value is supposed to *depend* on values of other variables. In order to analyse the effect of lean maturity over time on companies, two different financial indexes are chosen as dependent variables. Each of these variables will be analysed in a regression model separately from the others.

The first dependent variable is the Return on Equity (ROE) of companies in the sample over ten years. ROE is a common and broadly used profitability ratio, which measures the ability of generating profit in relation to the equity:

$$ROE = \frac{Net\ income}{Book\ value\ of\ equity}.$$

ROE provides a measure of remuneration, which companies obtain from past investments of shareholders. In *Graph 35*, it is depicted the average performance of this financial measure in lean companies (N=221) over the ten years considered for the regression. In this graph, the trend has a positive overall movement over time even if the index does not increase year by year. Especially after 2010 the ROE decreases and then it starts increasing slightly in 2013.

Graph 36*:Average performance of ROE across ten years*

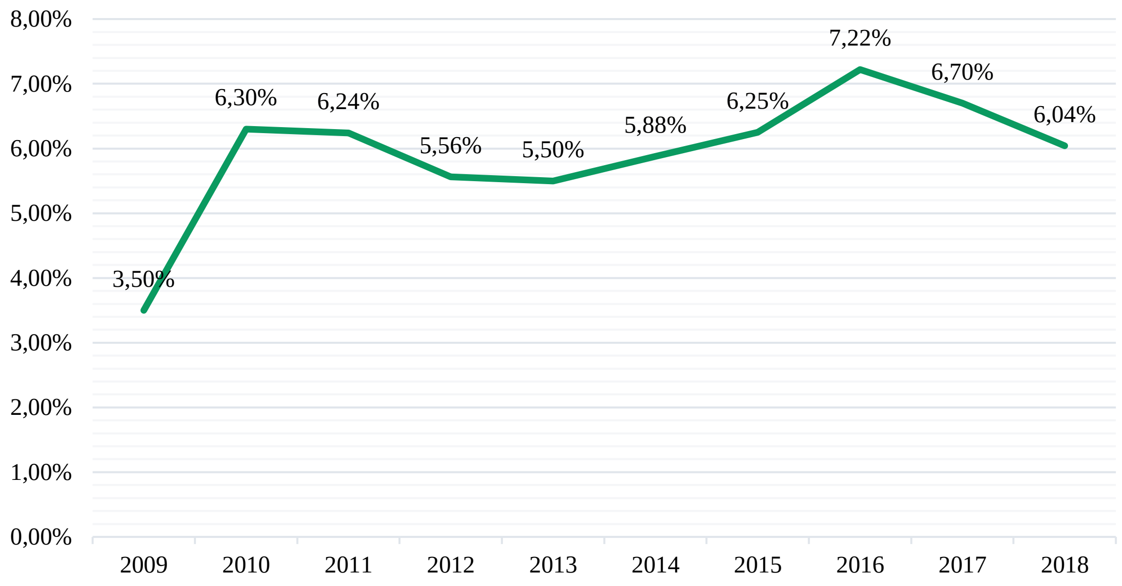


The second dependent variable is another very common measure, which is the Return on Assets (ROA). This index indicates the ability of any company at generating profit from its assets, both equity and debt:

$$ROA = \frac{Net\ income + Interest\ expense}{Book\ value\ of\ assets}.$$

The numerator of this ratio includes interest expense because in the denominator the debt is included. *Graph 36* illustrates the evolution of ROA across ten years for lean companies in the sample.

Graph 37*: Average performance of ROA across ten years*



In this graph there is a positive trend of ROA across time as well but less pronounced than ROE. ROE and ROA are two profitability ratios and high percentages of these ratios mean that the business is able to generate profit. The main difference between these two indexes is the role of debt. If the financial leverage was equal to zero, the two indexes would be the same. ROA has the advantage of being less sensitive to leverage ratio (cf. Berk and DeMarzo, 2014).

For each of these dependent variables, their values will be data that are reported from AIDA, hence the type of variables is continuous because it contains too many values to be countable.

Collecting the data across the time span of ten years, each firm is supposed to have ten observations. Therefore, theoretically the total number of values is supposed to be 4540, because the total number of firms in the sample is 454 and in this case the panel data would be *balanced.* Nonetheless, in the sample there are some missing values, thus the actual number of values are:

- ROE: the missing values of this financial ratio are 306, thus the total number of data is 4234;
-ROA: in this case, the missing values are 234 which drive the total number from 4540 to 4306.

Having a database in which some values are missing, the panel data are labelled as *unbalanced.*

4.2.2. The independent variable: lean maturity

Independent variables do not depend on other variables and they are used to observe their impact on dependent variable. Independent variables are also identified as explanatory variables or predictor variables. In this regression analysis, the independent variable is lean maturity of firms in the sample. As already explained, lean maturity is reached over time through experience, learning and training. Therefore, in the regression only companies implementing lean practices have a lean maturity equal or higher than zero. This is because non-adopters do not develop any level of lean maturity.

To build the independent variable, lean maturity is considered for each year of the chosen time span, thus from 2009 to 2018, and it is calculated as the difference between the year under consideration and the year of lean adoption. Thereby, those companies, that implemented lean techniques and tools long time ago, have a higher lean maturity than those companies that started to implement lean practices recently. As years advance, experience in lean production increases. In the sample, the *oldest* implementation in the sample took place in 1986, which means that the highest maturity among lean companies is equal to 32 years of lean experience. Hence, the values of the lean maturity range between 0 and 32.

In contrast to the dependent variables, the independent variable has countable set of values, which are clustered in four groups, one of which will be used as baseline in order to build the dummy variable. Within the four groups there are different levels of maturity according to which year of maturity we are referring to:

- the baseline category refers to all years of non-implementation, therefore it includes both the firms that do not use lean practices and those firms that do implement lean practices after 2009;
- a dummy variable refers to the first years of adoption, thus the maturity ranges from 0 to 4;
- another dummy variable contains the second period of maturity, which means the span of time from 5 to 10 years;
- the last dummy variable implies all lean maturity years from 11 to 32, hence it identifies high maturity.

This categorization is not done by accident, but many combinations are compared before choosing the definitive categories. In order to understand which levels are the most suitable, at the beginning the classes are many with few maturity years within them in order to see if there is a trend, what it is and if some categories are expressing the same results.

4.2.3. The control variables

To have an unbiased estimate of causal effect between the depend and independent variables, the explanatory variable must not suffer from omitted variable bias. Adding control variables aims to eliminate, or at least mitigate, this problem. Control variables are variables included in the regression model in order to recognize spurious effects. According to Wooldridge (2006) and York (2018), it is necessary to include variables that could have an impact on the dependent variable but that cannot be too much correlated to other independent variables because they reduce the error variance without inducing multicollinearity.

The answers to the survey providing information of companies in the sample are collected between 2018 and 2019 but much information could be different in the past, specifically between 2009 and 2018, which is the time span used in this statistical analysis. Therefore, control variables relying on survey information are supposed to be constant for the considered period. For this reason, the selected control variables, which presumably and intuitively do not change over time, are:

- *Corporate governance*, which is represented by a dummy variable with value equal to "1" whether the firm is a family business and a value equal to "0" whether the firm is not a family business;
- *Geographical position*, which refers to three dummy variables, the first one shows whether the firm is located in North-east Italy, the second one whether the firm is situated in North-west Italy and the last one whether the firm is in central and southern Italy. This classification is justified by the fact that only few firms are in the Centre and in the South, thus the firms in these two areas are clustered in order to build balanced categories;
- *Technological intensity*, these dummy variables are constructed in relation to sectors where companies of the sample operate. The four categories indicate respectively low intensity technology, medium-low technology, medium-high technology, and high technology;
- *Size*, in this case the number of employees of each year can be found in AIDA, thus a continuous variable is used.

These three main components of regression - dependent variables, independent variables and control variables- are summarized in *Table 7*.

Table 7: Components of regression models

	Function	Type	Sources
Return on Equity	Dependent	Continuous variable	AIDA
Return on Assets	Dependent	Continuous variable	AIDA
Lean maturity	Independent	Dummy variables Low lean maturity Medium lean maturity High lean maturity Otherwise	Survey
Corporate governance	Control	Dummy variable (0) Not Family business (1) Family business	Survey
Geographical position	Control	Dummy variables North-east North-west Centre and South	Survey
Technological intensity	Control	Dummy variables Low technology Medium-low technology Medium-high technology High technology	Survey
Size	Control	Continuous variable	AIDA

4.3.Regression models

In order to run our regressions, it is necessary first to make an important assumption regarding panel data models. First, in panel models the error term is decomposed into two different items: $\varepsilon_{it} = a_i + u_{it}$. The first item, usually identified as unobserved effect, includes all unobserved factors, which are constant over time and have an impact on the dependent variable. The second element is idiosyncratic error and, as opposed to unobserved effect, it includes time-varying factors affecting dependent variable.

There are two main methods to deal with this unobserved effect, for now it is considered the so-called random effects. Before applying this method, it must be assumed that the correlation in all time period between a_i and explanatory variables is equal to zero: $Corr(a_i, x) = 0$ (cf. Woolridge, 2006).

Hence, the generic regression model of panel data using random effects method is:

$$y_{it} = \beta_o + \beta_1 x_{it1} + \cdots + \beta_k x_{itk} + a_i + u_{it}$$

The subscript "i" refers to the cross-sectional dimension, at the same time the subscript "t" illustrates the time series dimension. The value β_0 is the intercept, thus it represents the value of the dependent variable when the independent variables are equal to zero. All the other β_k are the regression coefficients, which describe the average change in the dependent variable when the independent variable *k* changes of one unit, while the other explanatory variables do not change (cf. Hanke and Wichern, 2014). The idiosyncratic error and the unobserved effects can be unified in one unique variable, called composite error. Having depicted the generic regression model, it is now possible to fill the components with the variable of that specific regression, which is used to discuss our hypothesis. This regression model is expressed as:

$$y_{it} = \beta_0 + \beta_1 LeanMaturity_{it} + \beta_2 CorporateGovernance_i + \beta_3 GeographicalPosition_i + \beta_4 TechnologicalIntensity_i + \beta_5 Size_{it} + a_i + u_{it}$$

To complete the regression, we must replace not only the independent variables but also the dependent variable with one of the two financial indexes. The first index to be analysed is the return on equity (ROE) and the results of the regression are illustrated in *table 8*.

__Table 8:__ ROE as dependent variable in the regression model

R-squared: overall = 0.0069				Number of obs. = 4,196 Wald chi2(10) = 28.84 Prob > chi2 = 0.0013		
ROE	Coef.	Std. Err.	z	P> $\|z\|$	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**1.733196**	**.9543004**	**1.82**	**0.069**	**-.1371983**	**3.603591**
5-10 years	**4.726239**	**1.373138**	**3.44**	**0.001**	**2.034937**	**7.417541**
11-32 years	**7.478482**	**2.030134**	**3.68**	**0.000**	**3.499491**	**11.45747**
1. Corporate governance	**.6393853**	**1.637689**	**0.39**	**0.696**	**-2.570427**	**3.849197**
Geographical position	(baseline= North-east)					
North-west	**-2.111797**	**1.888432**	**-1.12**	**0.263**	**-5.813056**	**1.589462**
Centre and South	**-3.985808**	**2.580377**	**-1.54**	**0.122**	**-9.043253**	**1.071638**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-1.48462**	**1.93043**	**-0.77**	**0.442**	**-5.268193**	**2.298952**
Medium-high	**-.1906796**	**1.911255**	**-0.10**	**0.921**	**-3.93667**	**3.555311**
High	**7.402337**	**3.433792**	**2.16**	**0.031**	**.6722289**	**14.13245**
Size	**-.0090867**	**.0041121**	**-2.21**	**0.027**	**-.0171462**	**-.0010271**
Constant	**8.533779**	**2.052056**	**4.16**	**0.000**	**4.511822**	**12.55573**
$\boldsymbol{\sigma_{ai}}$	**14.209204**					
$\boldsymbol{\sigma_{uit}}$	**15.850525**					
$\boldsymbol{\rho}$	**.44556031**					

In *table 8* the results of the regression using random effects method are reported. The most interesting finding, which is also the subject of interest for the purpose of this analysis, is the impact of lean maturity on the financial ratio under consideration. The regression coefficients in relation to the independent variables show a clear positive impact and this impact increases over time. If companies have a low lean maturity, thus have from 0 to 4 years of lean experience, there is an increase on ROE equal to 1.73. Nonetheless, this result is slightly significant because the p-value is 0.069. The fully significant results are found from the fifth year of maturity, thus in the second and the third categories of lean maturity. From the fifth year to the tenth year of maturity the regression coefficient amounts to 4.73 and from the eleventh year to the thirty-second year of lean experience the coefficient amounts to 7.48. Hence, according to these results, we can state that at the beginning of lean implementation the values do not present a strong significance, but they are consistent with overall trend of the other lean maturity levels. Thereby, there is a positive, significant effect on financial performance, here embodied by the financial ratio ROE, and this impact has an increasing trend over time because the coefficient of category three is bigger than the coefficient of category two, which in turn is bigger than the coefficient of category one. The results suggest that not only lean companies have better performance than non-lean companies but also those lean companies having higher maturity have a higher financial performance than lean companies having lower maturity. Higher lean maturity means higher financial results.

The regression coefficients of control variables are mostly not significant, with the exception of the variables indicating “Technological intensity” and “Size”. Regarding the first mentioned variable, the only significant impact is related to high technological intensity, thus if companies belong to those sectors of high technology, they have a positive effect on ROE equal to 7.40 allegedly. Regarding the variable named Size, which is the only continuous variable in the model, it has a slightly negative effect on ROE, thus adding an employee decreases the financial measure of -0.009.

The coefficient of determination is the proportion of variability in the dependent variable that can be explained by the relationship with independent variables. The overall R-squared is far from being equal to 1 and this is justified by the fact that it would be unlike that a financial ratio as ROE is explained entirely by only these explanatory variables. Even if the coefficient of regression is low, the significance of the regression is tested by F-test, whose p-value is lower than 0.05, and this means that at least one variable is different from zero and it is useful to explain the dependent variable.

Lastly, the last part of *Table 8* determines the standard deviation of unobserved effect ($\boldsymbol{\sigma_{ai}}$), the standard deviation of idiosyncratic error ($\boldsymbol{\sigma_{uit}}$) and the variance due to a_i (ρ). This last output is calculated as: $\sigma_{ai}^2/(\sigma_{ai}^2+\sigma_{uit}^2)$. Rho is interclass correlation of the error and a value close to 1 suggests that the unobserved effect prevails over the idiosyncratic error, anyway this high value indicates that random effect method is more appropriate than a simple OLS regression.

Once that the regression model of ROE has been run and commented, the same procedure can be carried out for the regression of the other dependent variable, ROA. *Table 9* depicts the results of this regression model.

Table 9: ROA as dependent variable in the regression model

R-squared: overall = 0.0221						
				Number of obs. = 4,196 Wald chi2(10) = 38.00 Prob > chi2 = 0.0000		
ROA	Coef.	Std. Err.	z	P> $\lvert z \rvert$	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**1.001996**	**.3500134**	**2.86**	**0.004**	**.3159823**	**1.688011**
5-10 years	**1.80346**	**.5165462**	**3.49**	**0.000**	**.7910483**	**2.815872**
11-32 years	**2.859932**	**.7750364**	**3.69**	**0.000**	**1.340889**	**4.378975**
1. Corporate governance	**.7647938**	**.7193094**	**1.06**	**0.288**	**-.6450267**	**2.174614**
Geographical position	(baseline= North-east)					
North-west	**-.5229554**	**.8289905**	**-0.63**	**0.528**	**-2.147747**	**1.101836**
Centre and South	**-3.985808**	**2.580377**	**-1.54**	**0.122**	**-9.043253**	**1.071638**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-.0682893**	**.8486951**	**-0.08**	**0.936**	**-1.731701**	**1.595123**
Medium-high	**.5460349**	**.8397664**	**0.65**	**0.516**	**-1.099877**	**2.191947**
High	**5.705764**	**1.509596**	**3.78**	**0.000**	**2.747009**	**8.664518**
Size	**-.0029617**	**.0016377**	**-1.81**	**0.071**	**-.0061715**	**.0002481**
Constant	**4.840915**	**.8968842**	**5.40**	**0.000**	**3.083054**	**6.598775**
σ_{ai}	**6.3832218**					
σ_{uit}	**5.7248285**					
ρ	**.55421619**					

Without repeating redundant information, we can now comment the results of this regression model. The positive trend of lean maturity is confirmed also in this regression. In this model, the regression coefficient related to the first timeframe of lean experience is equal to 1.001996, therefore the presence of this level of maturity brings an increase of ROA equal to this amount. The coefficient of the second level is 1.80 and the coefficient of the last category is 2.86. All these three coefficients have p-value lower than 0.05, which means that they are all strongly significant. Thereby, the most important considerations are that lean adopter has more effectiveness than non-adopters and this effectiveness is higher when the maturity increases. The overall trend is increasing over time.

About the control variables, the only one to be significant is the high technological intensity. As before, it has a positive impact whether it is present and the regression coefficient of this dummy variable is equal to 5.71.

The same conclusions about R-squared, F-test and rho can be drawn also for this regression model. However, an important distinction between the two analysed regressions is the range of variability of values. The trend, indeed, is increasing over time in both cases but the values of the last regression have a slighter growth compared to the preceding growth. Furthermore, the intercept of ROA regression and the two standard deviations - σ_{ai} and σ_{uit}- have lower values than the values in *table 8*. These different extents in the increasing trend, in the intercept and in the standard deviations could be justified by the fact that ROE has values and range of variability higher than ROA as shown in *Graph 35* and *Graph 36*. Therefore, this moderate variability of ROA reoccurs also in regression values.

In conclusion, the studied regressions allow to make an essential statement because results in both cases confirm the hypothesis of this research. According to these outcomes, lean adoption has a positive effect on financial and economic performance over time.

4.4.The robustness analysis

Another relevant step in the statistical analysis is the verification and justification of those choices that lead to the final regressions in order to demonstrate the reliability of this study and of results.

4.4.1. Methodology

In the former paragraph, only the random effects method is used to run the regressions but it is not the only possible method to study panel data. Most of the times, when we deal with panel data the methods to choose from are notably two. The first one is the already mentioned random effects and the second is the fixed effects method. The main difference is that in the latter the unobserved effect a_i is allowed to be correlated to explanatory variables. For this reason, any time-invariant variable is removed through *fixed effects transformation*. The fixed effects method studies the impact of only those variables that change over time. In the analysed regressions, three out of four control variables are time-invariant dummy variables, thus they are removed when the fixed effects method is applied.

In *table 10*, the regression models are run by using this method to analyse the impact of lean experience, which is still the crucial relationship of this analysis. Following the assumption of fixed effects method, all control variables are omitted because constant over time, apart from the control variable "*Size*".

Table 10: *Regression models using fixed effects method*

ROE	Coef.	Std. Err.	z	P> $|z|$	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**3.250953**	**1.046868**	**3.11**	**0.002**	**1.198455**	**5.303451**
5-10 years	**8.634058**	**1.633929**	**5.28**	**0.000**	**5.430564**	**11.83755**
11-32 years	**14.80893**	**2.516385**	**5.89**	**0.000**	**9.875288**	**19.74258**
Size	**-.0069444**	**.0061103**	**-1.14**	**0.256**	**-.0189243**	**.0050354**
Constant	**6.921017**	**.7404098**	**9.35**	**0.000**	**5.469364**	**8.372671**

Table 10 *(Continued)*

ROA	Coef.	Std. Err.	z	P> $\lvert z \rvert$	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**1.296017**	**.3731762**	**3.47**	**0.001**	**.5643692**	**2.027666**
5-10 years	**2.572909**	**.5843852**	**4.40**	**0.000**	**1.427165**	**3.718653**
11-32 years	**4.358337**	**.902072**	**4.83**	**0.000**	**2.589737**	**6.126936**
Size	**-.0023671**	**.0022055**	**-1.07**	**0.283**	**-.0066912**	**.0019569**
Constant	**5.393909**	**.2655426**	**20.31**	**0.000**	**4.873287**	**5.914531**

These regressions confirm the results of the previous paragraph because in both models we find a positive impact of lean maturity on ROE and on ROA. In these regressions, all categories of lean maturity are significant. Using fixed effects method leads to same conclusions, even if the numerical values are amplified both for ROE and for ROA. Probably, this means that in reality the actual values are even higher; the main finding still remains the confirmation of a positive and significant impact on economic and financial performance increasing in time thanks to lean adoption.

Moreover, in order to choose between random effects and fixed effects, the Hausman test can be executed. Hausman test aims to test the null hypothesis according to which the correlation between unobserved effect and explanatory variables is equal to zero, thus the random effects method is more appropriate, $H_0\colon Corr(a_i, x_{it}) = 0$. *Table 11* summarizes the results of Hausman tests for both regressions. If the difference between the random effects and fixed effect predictors is significant the null hypothesis must be rejected.

***Table 11**: Hausman tests*

Hausman test 1	Coefficient		Difference	Std. Err.
ROE	RE (b)	FE (B)	(B-b)	
Lean Maturity	(baseline= No lean)			
0-4 years	**1.733196**	**3.250953**	**1.649304**	**.4405667**
5-10 years	**4.726239**	**8.634058**	**4.096554**	**.9115745**
11-32 years	**7.478482**	**14.80893**	**8.207809**	**1.49858**
Test Summary	Chi-Squared statistic (3)		Prob>chi2	
	32.65		**0.0000**	
Hausman test 2	Coefficient		Difference	Std. Err.
ROA	RE (b)	FE (B)	(B-b)	
Lean Maturity	(baseline= No lean)			
0-4 years	**1.001996**	**1.296017**	**.2940215**	**.1294261**
5-10 years	**1.80346**	**2.572909**	**.7694487**	**.2732875**
11-32 years	**2.859932**	**4.358337**	**1.498405**	**.461576**
Test Summary	Chi-Squared statistic (3)		Prob>chi2	
	10.06		**0.0181**	

Both Hausman tests provide a significant difference between the two estimators, indeed both p-values are smaller than 0.05. Hence, the most suitable method would be fixed effects according to results of Hausman tests. Nonetheless, as already illustrated, the conclusions of both methods match, providing a positive trend related to lean maturity. For this reason, it was feasible to use in the analysis the random effects method, whose advantage is the possibility of evaluating the impact of time-constant variables.

Panel data can be studied also using the pooled OLS method, thus a linear regression model. Nevertheless, this method is not usually applied because it is less suitable and it could lead to inaccurate results. Basically, it ignores the characteristics of panel data and it considers data as a broad cross-sectional model. In *Table 12*, the pooled OLS regressions are run and the results are completely opposite compared to the previous results.

***Table 12**: Pooled OLS regressions*

ROE	Coef.	Std. Err.	z	P> |*z*|	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**1.345329**	**.9246353**	**1.45**	**0.146**	**-.4674556**	**3.158114**
5-10 years	**1.284399**	**1.124436**	**1.14**	**0.253**	**-.9201022**	**3.4889**
11-32 years	**-1.818277**	**1.439557**	**-1.26**	**0.207**	**-4.640586**	**1.004032**
1. Corporate governance	**.5742564**	**.7200263**	**0.80**	**0.425**	**-.8373841**	**1.985897**
Geographical position	(baseline= North-east)					
North-west	**-1.493767**	**.8291621**	**-1.80**	**0.072**	**-3.119372**	**.1318389**
Centre and South	**-4.175928**	**1.113418**	**-3.75**	**0.000**	**-6.358829**	**-1.993027**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-1.667812**	**.8442439**	**-1.98**	**0.048**	**-3.322986**	**-.0126378**
Medium-high	**.3402672**	**.83648**	**0.41**	**0.684**	**-1.299686**	**1.98022**
High	**6.533776**	**1.509963**	**4.33**	**0.000**	**3.573432**	**9.49412**
Size	**-.0068535**	**.0023271**	**-2.95**	**0.003**	**-.0114159**	**-.0022912**
Constant	**9.074001**	**.9168011**	**9.90**	**0.000**	**7.276576**	**10.87143**

Table 12 (Continued)

ROA	Coef.	Std. Err.	z	P> |z|	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**.7322098**	**.387534**	**1.89**	**0.059**	**-.027562**	**1.491982**
5-10 years	**.7791453**	**.4716291**	**1.65**	**0.099**	**-.145498**	**1.703789**
11-32 years	**-.295514**	**.6062932**	**-0.49**	**0.626**	**-1.48417**	**.8931426**
1. Corporate governance	**.7009445**	**.3012657**	**2.33**	**0.020**	**.1103038**	**1.291585**
Geographical position	(baseline= North-east)					
North-west	**-.408349**	**.3474417**	**-1.18**	**0.240**	**-1.08952**	**.2728211**
Centre and South	**-1.68686**	**.4671242**	**-3.61**	**0.000**	**-2.60268**	**-.7710577**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-.050346**	**.353726**	**-0.14**	**0.887**	**.7438374**	**.6431441**
Medium-high	**.718297**	**.3503004**	**2.05**	**0.040**	**.0315221**	**1.405072**
High	**5.771127**	**.632051**	**9.13**	**0.000**	**4.531971**	**7.010283**
Size	**-.002330**	**.0009794**	**-2.38**	**0.017**	**-.004250**	**-.00041**
Constant	**5.054713**	**.3836713**	**13.17**	**0.000**	**4.302513**	**5.806912**

To conclude, this last method has been discarded because it is the least convenient and, thus, it has misleading results for the panel analysis. Furthermore, even if fixed effects is the most appropriate method according to Hausman test, random effects model has been selected because it allows to draw the same conclusions of fixed effects model and also it allows to study the effects of those variables that do not change over time.

4.4.2. The choices behind explanatory variables

As already anticipated, the categorization of lean maturity variable does not cluster years of lean experience without following a logic behind but, on the contrary, many combinations have been compared in order to select the most representative categories. It is useless to report every tested combination. Thereby, in *Table 13* it is illustrated an emblematic classification, which clarifies and justifies the decision of final grouping. The control variables are not depicted because they are not a topic of interest for now.

Table 13*: Regression models with another lean maturity categorization*

ROE	Coef.	Std. Err.	z	P> $\|z\|$	[95% Coef.	Interval]
Lean Maturity	(baseline= No lean)					
0-1 years	**1.556827**	**1.153426**	**1.35**	**0.177**	**-.7038461**	**3.8175**
2-4 years	**1.884814**	**1.185955**	**1.59**	**0.112**	**-.4396141**	**4.209243**
5-7 years	**3.896894**	**1.51963**	**2.56**	**0.010**	**.9184749**	**6.875314**
8-10 years	**6.349382**	**1.782547**	**3.56**	**0.000**	**2.855654**	**9.843111**
11-16 years	**8.156666**	**2.11169**	**3.86**	**0.000**	**4.017829**	**12.2955**
17-24 years	**7.490114**	**3.322502**	**2.25**	**0.024**	**.9781302**	**14.0021**
25-32 years	**4.516341**	**10.65799**	**0.42**	**0.672**	**-16.37294**	**25.40562**

***Table 13** (Continued)*

ROA	Coef.	Std. Err.	z	P> |*z*|	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-1 years	**.8605121**	**.418679**	**2.06**	**0.040**	**.0399164**	**1.681108**
2-4 years	**1.165791**	**.4347315**	**2.68**	**0.007**	**.3137324**	**2.017849**
5-7 years	**1.538321**	**.5641724**	**2.73**	**0.006**	**.4325639**	**2.644079**
8-10 years	**2.525983**	**.6691412**	**3.77**	**0.000**	**1.21449**	**3.837475**
11-16 years	**3.199962**	**.8064597**	**3.97**	**0.000**	**1.61933**	**4.780594**
17-24 years	**3.152149**	**1.248369**	**2.53**	**0.012**	**.7053899**	**5.598908**
25-32 years	**1.345169**	**4.090604**	**0.33**	**0.742**	**-6.672267**	**9.362605**

Table 13 suggests that there is an increasing trend in lean maturity, as in the regressions of the statistical analysis. The monotonous aspect of the trend is confirmed by running another regression, where lean maturity as continuous variable and its square are investigated. The values of lean maturity variable not only are positive and significant for both financial indexes but also they are consistent with the values of our regression analysis; whereas the values of the square of lean maturity are not significant, which means that there are not additional effects, hence trend is supposed to be linear. We decide to cluster the levels of lean experience, which present an impact more or less similar, considering both the outcomes of the explanatory variable for ROE and of the explanatory variable for ROA. Moreover, the last level of lean maturity shows a lower value, but it is not alarming because this result is not significant and the database contains only one firm having more than 24 years of lean experience, which explains the high standard error. In order to create balanced categories, the first two levels are merged in a single category, the levels “5-7 years” and “8-10 years” create a single cluster and, eventually, the levels “11-16 years”, “17-24 years” and “25-32 years” are part of the same class.

The category “baseline”, representing the periods without lean implementation, is not classified with any other category.

Another important explanation must be given for the control variables. *Table 14* illustrates regressions, which justify the choices related to “Geographical position” and “Size” variables. The variable “Geographical position” in *table 14* includes the typical division between North -used as baseline-, Centre and South areas. Nevertheless, firms in the sample are not evenly distributed, especially in southern Italy, where there are only three firms and therefore its standard error is high. In order to build more homogenous groups, in the final analysis the areas “South” and “Centre” are included in the same class and the category “North” is splitted in two different categories – “north-east” and “north-west”- because it is the area where most companies are located.

Moreover, to capture any marginal impact of “Size” variable, in *table 14* the quadratic functions of this variable are illustrated but none of them is significant, thus it is not useful to include them in the final regression.

***Table 14**: Regression models using other control variables*

ROE	Coef.	Std. Err.	z	P> |*z*|	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**1.819445**	**.9570867**	**1.90**	**0.057**	**-.056418**	**3.6953**
5-10 years	**4.824622**	**1.375191**	**3.51**	**0.000**	**2.129297**	**7.519948**
11-32 years	**7.492149**	**2.030316**	**3.69**	**0.000**	**3.512803**	**11.47149**
1. Corporate governance	**.3734217**	**1.629445**	**0.23**	**0.819**	**-2.82023**	**3.567076**
Geographical position	(baseline= North-east)					
North-west	**-2.58040**	**2.657488**	**-0.97**	**0.332**	**-7.788986**	**2.628177**
Centre and South	**-10.50906**	**8.727017**	**-1.20**	**0.229**	**--27.6137**	**6.59558**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-1.393744**	**1.922081**	**-0.73**	**0.468**	**-5.160954**	**2.373465**
Medium-high	**.0120622**	**1.904314**	**0.01**	**0.995**	**-3.720324**	**3.744449**
High	**7.053972**	**3.413141**	**2.07**	**0.039**	**.364339**	**713.7436**
Size	**-.0149398**	**.0079621**	**-1.88**	**0.061**	**-.0305452**	**.0006656**
Size^2	**7.11e-06**	**8.03e-06**	**0.88**	**0.376**	**-8.64e-06**	**.0000229**
Constant	**8.523061**	**2.073497**	**4.11**	**0.000**	**4.459082**	**12.58704**

Table 14 *(Continued)*

ROA	Coef.	Std. Err.	z	P> $|z|$	[95% Coef. Interval]	
Lean Maturity	(baseline= No lean)					
0-4 years	**.9769315**	**.3509979**	**2.78**	**0.005**	**.2889882**	**1.664875**
5-10 years	**1.773754**	**.5174524**	**3.43**	**0.001**	**.7595657**	**2.787942**
11-32 years	**2.818502**	**.7756533**	**3.63**	**0.000**	**1.29825**	**4.338755**
1. Corporate governance	**.7695563**	**.718141**	**1.07**	**0.284**	**-.6379742**	**2.177087**
Geographical position	(baseline= North-east)					
North-west	**-1.004085**	**1.1743**	**-0.86**	**0.393**	**-3.305671**	**1.2975**
Centre and South	**-3.444873**	**3.862897**	**-0.89**	**0.373**	**--11.01601**	**4.126266**
Technological intensity	(baseline= Low intensity)					
Medium-low	**-.0397288**	**.848205**	**-0.05**	**0.963**	**-1.70218**	**1.622722**
Medium-high	**.5255764**	**.8396217**	**0.63**	**0.531**	**-1.120052**	**2.171205**
High	**5.665079**	**1.506255**	**3.76**	**0.000**	**2.712875**	**8.617284**
Size	**.0000302**	**.0031348**	**0.01**	**0.992**	**-.0061139**	**.0061743**
Size^2	**-3.35e-06**	**3.03e-06**	**-1.10**	**0.270**	**-9.30e-06**	**2.60e-06**
Constant	**4.510547**	**.9059066**	**4.98**	**0.000**	**2.735002**	**6.286091**

In conclusion, the variables and the method used in the final regression models are selected because they are considered the most effective and representative for the purpose of this statistical analysis.

CHAPTER 5: CONCLUSIONS

5.1. Main findings of the empirical analysis

Lean thinking is widespread broadly because it is considered an efficient method to overcome a tough competition in the market and sudden changes in customer demand. In the sample almost half of companies carries out this approach due to several and different reasons, among them the necessity of operational improvements as main motivation. Translating these operational improvements into financial success is not a natural and automatic process (cf. Oliver & Hunter, 1998). In literature many researchers dedicate theoretical studies and empirical investigations about the link between lean philosophy and business performance. Nonetheless, even nowadays the effect of lean on financial measures is neither clear nor unequivocal. The present paper is aligned to the point of view claiming a positive impact of lean tools on financial and economic performance and it aims to provide its contribute on this issue, stressing the function of time. The sample offers a good variety of firms in relation to lean experience, ranging from zero year of lean maturity to thirty-two years.

The outcomes of panel regressions indicate two important findings. The first one is the stronger financial achievement of lean companies compared to non-lean companies. Indeed, at each lean maturity level the economic measures – as dependent variables - gain an increase in financial performance. The second finding is the identification of a trend over time resulting from the relationship between financial indexes and four categories of lean experience as independent variables. It follows that this trend is positive and significant over time, which means that high-maturity lean organizations have higher financial success than low-maturity lean organization. Hence, lean companies having different level of lean experience tend to have different outcomes according to the development of lean practices. As the lean maturity increases, also financial performance positively and significantly increases over the considered timespan of ten years.

Additionally, it has been illustrated that using another regression method, the fixed effects method, the outcomes, which are all positive and significant, have higher values. These amplified values could demonstrate that the actual effect of lean maturity is even higher.
In conclusion, the hypothesis of this thesis is confirmed and, according to main findings, the lean adoption has a positive and significant impact on economic and financial performance over time. Thereby, the implementation of lean philosophy leads to beneficial results for companies, even though the entire contribution is developed and visible over time and not immediately.
The investigation contributes to lean literature because it provides a deeper analysis of lean consequences for Italian manufacturing firms by using an appropriate methodology exploiting fully longitudinal data. Other scholars try to understand the role of lean maturity on financial indicators but usually either they limit the research by comparing the situation before and after lean adoption without studying degrees of maturity (Kennye and Wempe, 2002) or they treat lean variable only as a continuous variable (Galeazzo, 2019) without taking advantage of relevant information offered by panel data. Therefore, the originality of this thesis is the importance given to a specific and suitable statistical method, which allows to embrace the multidimensional quality of the database.

5.2. Limitations and further possible investigations

If on one hand the thesis grants contributions to lean literature, on the other one, it presents some limitations, that must be disclosed.

In *Chapter 3* firms in the sample are deeply described relying on information provided by the firms themselves in the submitted surveys. Assuming the accuracy and authenticity of these answers, the retrieved data contribute to build our regression models in the statistical analysis. Nevertheless, the first limitation refers to this assumption. It cannot be assured that participants of the survey have enough knowledge to properly and objectively answer.

Another limitation of the paper concerns the number of firms having high levels of lean maturity. In the sample, most of the companies (63%) implements lean practices over the last decade, hence, the majority reaches low levels of lean experience. There is only one company having more than twenty-four years of maturity in lean manufacturing. If the sample contained lean companies with higher maturity, another type of categorization according to maturity levels could be allowed, leading to more detailed results for high levels of maturity.

Limitations can suggest other possibilities for further investigations, which strengthen the outcomes. First of all, the first opportunity refers to the recruitment of other companies implementing lean tools and techniques in order to have a more complete sample in terms of lean maturity. Furthermore, the variable of lean maturity could interact with control variables in order to study whether different characteristics of lean companies facilitate the financial performance in relation with lean maturity. For example, we tried to study the interaction between the technological intensity of companies and lean maturity by clustering low with medium-low intensity and medium-high with high intensity. The results do not highlight any significant difference among the two groups. Further interactions can be made, especially, with a larger sample.

In this thesis, the focus is on the role of lean maturity over time but the analysis could be expanded on the role of lean intensity over time. An interesting perspective could be the investigation of diseconomies of scale. Specifically, whether the enlargement of lean intensity must be carried out gradually over time or not. For this analysis, the function of learning is crucial because it would help to understand whether companies need time to learn new operational procedure, thus whether the implementation of many lean tools simultaneously is source of costs.

In conclusion, future investigations could make their contributions to lean literature by exploring new interesting aspects of relationship between lean philosophy and business performance. Moreover, they could confirm the findings obtained in this paper.

BIBLIOGRAPHICAL REFERENCES

Ahmad, A., Mehra, S., and Pletcher, M. (2004). The perceived impact of JIT implementation on firms' financial/growth performance. *Journal of Manufacturing Technology Management*, Vol. 15 No. 2, pp. 118-30.

Ahuja, I. P. S., & Khamba, J. S. (2008). Total productive maintenance: Literature review and directions. *International Journal of Quality & Reliability Management*, 25, 709–756.

Allwood, & Lee, W. L. (2004). The impact of job rotation on problem solving skills. *International Journal of Production Research*, 42 865-881

Appelbaum, S. H., St-Pierre, N., & Glavas, W. (1998). Strategic organizational change: the role of leadership, learning, motivation and productivity. *Management Decision*, 36(5), 289-301.

Argyris, C. (1991). Teaching smart people how to learn. *Harvard Business Review*, May-June, pp. 99-109.

Arthur, J. B., & Huntley, C. L. (2005). Ramping up the organizational learning curve: Assessing the impact of deliberate learning on organizational performance under gainsharing. *Academy of Management Journal*, 48(6), 1159–1170.

Bayou, M., & de Korvin, A. (2008). Measuring the leanness of manufacturing systems – a case study of ford motor company and general motors. *Journal of Engineering and Technology Management*, 25(4), 287–304.

Balakrishnan, R., Linsmeier, T.J. and Venkatachalam, M. (1996). Financial benefits from JIT adaption: effects of customer concentration and cost structure. *The Accounting Review*, Vol. 71 No. 2, pp. 183-205.

Barker, B. (1998). The identification of factors affecting change towards best practice in manufacturing organisations. *Management Decision*, Vol. 36 No. 8, pp.549–556.

Belekoukias, I., Garza-Reyes, J. A., & Kumar, V. (2014). The impact of lean methods and tools on the operational performance of manufacturing organisations. *International Journal of Production Research*, 52(18), 5346-5366.

Berk, J. and DeMarzo, P. (2014) *Corporate Finance*. 3rd Edition, Pearson, Boston.

Besanko, D., Dranove, D., & Shanley, M. (2004). *Economics of strategy*. Hoboken, NJ: Wiley.

Bevilacqua, M., Ciarapica, F. E. and De Sanctis, I. (2017). Relationships between Italian companies' operational characteristics and business growth in high and low lean performers. *Journal of Manufacturing Technology Management*, Vol. 28 No. 2, pp. 250-274.

Boschetto, I. (2019). Economic and financial returns of lean over time: empirical evidence from Italian manufacturing firms. *Master Thesis*, University of Padua.

Brah, S. A., Li Wong, J., & Madhu Rao, B. (2000). TQM and business performance in the service sector: A Singapore study. *International Journal of Operations & Production Management*, 20(11), 1293–1312.

Callen, J.L., Fader, C. and Krinsky, I. (2000). Just-in-time: a cross-sectional plant analysis. *International Journal of Production Economics*, Vol. 63 No. 3, pp. 277-301.

Capgemini (2005). How to Implement Lean Successfully and Deliver Results that Last [online] http://www.capgemini.com

Castle, A. and Harvey, R. (2009). Lean information management: the use of observational data in health care. *International Journal of Productivity and Performance Management*, Vol. 58 No. 3, pp. 280-299.

Chapman, C. D. (2005). Clean house with lean 5s. *Quality Progress*, 38(6):27-32.

Cool, K., Dierickx, I. and Almeida, C. L. (2016). Diseconomies of time compression. In M. Augier and D. J. Teece (Eds.), *The palgrave encyclopedia of strategic management*. London, England: Palgrave Macmillan.

Corredor, P. and Goñi, S. (2011). TQM and performance: Is the relationship so obvious?. *Journal of Business Research*, Vol. 64 No. 8, pp. 830-838.

Deaton, A. (1985). Panel Data from Time Series of Cross-Sections. *Journal of Econometrics* 30: 109-126.

Dimovski, V. (1994): Organizational Learning and Competitive Advantage, PhD Thesis, Cleveland.

Emiliani, M. L. (1998*)*. Lean Behaviors*. Management Decision*, Vol. 36 No. 9, pp. 615-631.

Faron, A. (2012). Lean management and centralization in the light of research in selected companies. *Production Management - contemporary approaches - selected aspects, Publishing House of Poznan University of Technology*, pp.23-40.

Fullerton, R.R., McWatters, C.S. and Fawson, C. (2003). An examination of the relationship between JIT and financial performance. *Journal of Operations Management*, Vol. 21 No. 4, pp. 383-404.

Furlan, A. and Galeazzo, A. (2017). Lean bundles and configurations: a fsQCA approach. *Journal of Operations & Production Management*, Vol. 38 No. 2, pp. 513-533.

Galeazzo, A. (2019). Degree of leanness and lean maturity: exploring the effects on financial performance. *Total Quality Management & Business Excellence*, pp. 1-19.

Garza-Reyes, J. A., Belekoukias, I., Garza-Reyes, J., & Kumar, V. (2014). The impact of lean methods and tools on the operational performance of manufacturing organisations. *International Journal of Production Research*, 52(18), 5346-5366.

Garza-Reyes, J.A., Oraifige, I., Soriano-Meier, H., Forrester, P.L. and Harmanto, D. (2012), The development of a lean park homes production process using process flow and simulation methods. *Journal of Manufacturing Technology Management*, Vol. 23 No. 2, pp. 178-197.

Hanke, J. and Wichern, D., (2014). *Business Forecasting*. 9th ed. Harlow: Pearson.

Hendricks, K. B. and Singhal, V. R. (2001). Firm characteristics, total quality management, and financial performance. *Journal of Operations Management*, Vol. 19, No. 3, pp. 269-285.

Hines, P. (2010) How to create and sustain a lean culture. *Training Journal,* pp.58–62.

Hines, P. (2011) Lean systems thinking: a roadmap for operational excellence. BCCC 2011 Annual Conference [online].

Hofer, C., Eroglu, C. and Hofer, A. R. (2012). The effect of lean production on financial performance: the mediating role of inventory leanness. *International Journal of Production Economics*, Vol. 138, No. 2, pp. 242-253.

Holweg, M. (2007). The genealogy of lean production. *Journal of Operations Management*, Vol. 25 No. 2, pp. 420-37.

Hsiao, C. (1985) Benefits and limitations of panel data. *Econometric Reviews*, 4:1, 121-174

Huson, M., & Nanda, D. (1995). The impact of just-in-time manufacturing on firm performance in the US. *Journal of Operations Management*, *12*(3-4), 297-310.

Inman, R.A. and Mehra, S. (1993). Financial Justification of JIT Implementation. *International Journal of Operations & Production Management*, Vol. 13 No. 4, pp. 32-39.

Jacobs, B.W., Swink, M. and Linderman, K. (2015). Performance effects of early and late six sigma adoptions. *Journal of Operations Management*, Vol. 36, pp. 244-257.

Jayaram, J., Ahire, S. L., & Dreyfus, P. (2010). Contingency relationships of firm size, TQM duration, unionization, and industry context on TQM implementation—a focus on total effects. *Journal of Operations Management*, 28(4), 345–356.

Jørgensen, F., Matthiesen, R., Nielsen, J., & Johansen, J. (2007). Lean maturity, lean sustainability. In J. Olhager & F. Persson (Eds.), *Advances in Production Management International Journal of Supply Chain, Operation Management and Logistics*, Vol. 1 Issue 1, pp. 01-35.

Kaplan, M., Ogut, A, Bickes D. M. & Kaplan A. (2014). The relationship between organizational learning and financial performance: A study of small-sized business in Turkey. *Journal of WEI Business and Economics*, Volume 3 Number 2, pp. 17-24.

Keating, E. K., Oliva, R., Repenning, N. P., Rockart, S., and Sterman, J. D. (1999). Overcoming the improvement paradox. *European Management Journal*, 17(2), 120–134.

Kinney, M.R. and Wempe, W.F. (2002). Further evidence on the extent and origins of JIT's profitability effects. *The Accounting Review*, Vol. 77 No. 1, pp. 203-225.

Kolberg and D. Zühlke, (2015). Lean Automation Enabled by Industry 4.0 Technologies. *IFACPapersOnLine*, vol. 48, no. 3, pp. 1870–1875.

Kootanaee, A. J., Babu. K. and Talari, H. F. (2013), Just-In-Time Manufacturing System: From Introduction to Implement. *International Journal of Economics, Business and Finance*. Vol. 1, No. 2.

Krafcik, J.F. (1988) Triumph of the Lean Production System. *Sloan Management Review*, 30, 41-52.

Lam, S.S.K. (1998). Organizational Performance and Learning Styles in Hong Kong. *Journal of Social Psychology*, 138, 3, 401-403

Lapré, M. A., Mukherjee, A. S., & Van Wassenhove, L. N. (2000). Behind the learning curve: Linking learning activities to waste reduction. *Management Science*, 46(5), 597–611.

Lewis, M.A. (2000). Lean production and sustainable competitive advantage. *International Journal of Operations and Production Management*, Vol. 20 No. 8, pp. 959-978

Liker, J. K. 2003. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. New York: McGraw-Hill.

Liker, J. K., & Morgan, J. M. (2006). The Toyota Way in Services: The Case of Lean Product Development. *The Academy of Management Perspectives*, *20*(2), 5–20.

Limoncelli, T., & Hogan, C. J. (2002). *The practice of system and network administration*. Boston: Addison-Wesley.

Losonci, D. and Demeter, K. (2013). Lean production and business performance: international empirical results. *Competitiveness Review* 23:3, 218-233.

Marín García, JA.; Bonavía Martín, T. (2015). Relationship between employee involvement and lean manufacturing and its effect on performance in a rigid continuous process industry. *International Journal of Production Research*. 53(11):3260-3275.

MCCrerry, J. K. and Krajewski, L. J., (1999). Improving performance using workforce flexibility in an assembly environment with learning and forgetting effects. *International Journal of Production Research*, 37(9), 2031–2058.

Nesensohn, C. et al (2014). Maturity and maturity models in lean construction. *Australasian Journal of Construction Economics and Building*, 14 (1) 45-59

Netland, T. H. (2016). Critical success factors for implementing lean production: The effect of contingencies. *International Journal of Production Research*, 54(8), 2433–2448

Nordin, N., Deros, B., Wahab, D., and Rahman, M. (2012). A framework for organisational change management in lean manufacturing implementation. *International Journal of Services and Operations Management*, Vol. 12, No. 1, pp. 101-117.

Ohno, T. (1988). *Toyota production system: beyond large-scale production*. CRC Press.

Oliver, N. and Hunter, G. (1998). The financial impact of `Japanese' manufacturing methods. *Manufacturing in Transition*, Chapter 5, Routledge & Kegan Paul, London.

Oparanma, A.O., & Nwaeke, L.I. (2015). Impact of job rotation on organizational performance. *British Journal of Economics, Management and Trade*, 7(3), 183-187.

Pereira, A. C., Dinis-Carvalho, J., Alves, A. C., and Arezes, P. (2019). How Industry 4.0 can enhance lean practices. *FME Transactions*, 47(4), 810–822.

Poksinska. B and Swartling, D. (2018). From successful to sustainable Lean production – the case of a Lean Prize Award Winner. *Total Quality Management & Business Excellence*, 29:9-10, 996-1011.

Rewers P., Trojanowska J. and Chabowski P. (2016) Tools and methods of Lean Manufacturing - a literature review, proceedings of 7th International Technical Conference. *Technological forum*, Czech Republic, 28-30.06.2016, pp.135-139.

Ryan, N., Williams, T., Charles, M. and Waterhouse, J. (2008). Top-down organizational change in an Australian Government agency. *International Journal of Public Sector Management*, Vol. 21 No. 1, pp. 26-44.

Shamah, R. (2014). Measuring and building lean thinking for value creation in supply chains. *International Journal of Lean Six Sigma*, Vol. 4 No. 1, pp. 17-35.

Shang, G. and Low, S. P. (2013). The Toyota Way model: an alternative framework for lean construction. *Total Quality Management & Business Excellence*. 25:5-6, 664-682.

Slack, N., Brandon-Jones, A. and Johnston, R. (2013). *Operation Management*. 7th ed., Pearson Education.

Soliman, M. H.A. (2016). Jidoka - The missing pillar! *Engineering and Science Service*, pp. 1-7.

Swink, M., & Jacobs, B. W. (2012). Six Sigma adoption: Operating performance impacts and contextual drivers of success. *Journal of Operations Management*, 30(6), 437–453.

Taj, S. and Berro, L. (2006). Application of Constrained Management and Lean Manufacturing in Developing Best Practices for Productivity Improvement in an Auto-Assembly Plant. *International Journal of Productivity and Performance Management,* 55, 332-345.

Tyagi, Satish & Choudhary, Alok & Cai, Xianming & Yang, Kai, 2015. Value stream mapping to reduce the lead-time of a product development process. *International Journal of Production Economics,* Elsevier, vol. 160(C), pp 202-212.

Uotila, J., Maula, M., Keil, T. and Zahra, S.A. (2009). Exploration, exploitation, and financial performance: analysis of S&P 500 corporations. *Strategic Management Journal*, Vol. 30 No. 2, pp. 221-231.

Villalba-Diez, J., Ordieres-Mere, J. and Rubio-Valdehita, S. (2016). Lean Learning Patterns. (CPD)nA vs. KATA. *Procedia CIRP*, 54, 147–151.

Wilson, L. (2010). *How to implement lean manufacturing*. New York: McGraw-Hill.

Womack, J. P. and Jones, D. T. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York: Simon & Schuster.

Womack, J. P., Jones, D. T. and Roos, D. (1990*). The machine that changed the world*. New York: Rawson Associates.

Wooldridge, J. M. (2006). *Introductory econometrics: A modern approach*. Mason, OH: Thomson/South-Western.

Yang, M. M., Hong, P., and Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics*, 129 (2), pp. 251-261.

York, R. (2018). Control variables and causal inference: a question of balance, International *Journal of Social Research Methodology*.

RINGRAZIAMENTI

A conclusione di questo elaborato, desidero menzionare coloro che mi hanno aiutato durante il mio percorso universitario.

Ringrazio il mio relatore Andrea Furlan e il mio correlatore Adriano Paggiaro, che mi hanno seguito con grande disponibilità e gentilezza nell’elaborazione e nella stesura della tesi.

Ringrazio i Colleghi dell’Università di Padova e gli amici conosciuti in Erasmus per aver reso questi anni indimenticabili.

Ringrazio i miei amici di sempre, Marco, Martino e Chiara, che hanno condiviso con me tante avventure e che mi hanno saputo ascoltare in ogni occasione.

Grazie ad Alberto per avermi sempre spronato a dare il meglio di me e per starmi accanto durante le difficoltà e i successi.

Ringrazio i miei fratelli Giorgio e Laura, che mi hanno sempre sostenuto e supportato, ognuno a modo suo.

Infine, un ringraziamento speciale va a mia madre che mi ha formata e mi ha guidata nelle mie scelte.