UNIVERSITA' DEGLI STUDI DI PADOVA

DIPARTIMENTO DI SCIENZE ECONOMICHE ED AZIENDALI
"M.FANNO"

CORSO DI LAUREA MAGISTRALE IN
BUSINESS ADMINISTRATION

TESI DI LAUREA

"LEAN AND RESILIENCE: AN EMPIRICAL STUDY OF THE PERFORMANCE OF ITALIAN MANUFACTURING FIRMS "

RELATORE:
CH.MO PROF. ANDREA FURLAN

LAUREANDO/A: SOFIA BRESSAN
MATRICOLA N. 1206052

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.

Firma dello studente

INDEX

INTRODUCTION

Lean management emerged in the second half of the twentieth century in Japan, and in the years since its introduction an increasing number of companies worldwide has adopted this philosophy, and its related tools and techniques, believing in the potential benefits it could bring to their production systems in terms of efficiency and flexibility. Literature has offered support to this belief, providing solid arguments in favor of a positive effect of lean adoption on operational and financial performance of firms, achieved through the reduction of waste in production activities, the improved asset utilization and the increased ability to deliver products with rapidity and flexibility.

However, the world in which firms operate today is not the same in which they operated twenty or thirty years ago, when lean was first introduced. The business scenario today is more competitive and dynamic, and disruptions, that can range from issues in the supply chain to large scale global shocks, occur frequently and spread more rapidly through globalized supply chains. If there is something that the events of 2020 have proven is how changes are unpredictable, and how disruptive they can be to the sustainability of businesses. In this context, being efficient is still necessary but no longer sufficient, and firms that want to retain a sustainable performance over time need to prove that they can also be resilient, withstanding disruptions and adapting quickly to changes in highly volatile environments.

Since both efficiency and resilience appear to be key capabilities to ensure the survival of businesses, it’s important to understand if, and eventually how, they can be balanced. Therefore, the positive impact of lean management on performance needs to be re-evaluated from a new perspective, assessing its compatibility with the need to build resiliency. Evaluating this issue is however not straightforward, as the concepts are in an apparent trade-off. On the one hand, resilience-building relies on the employment of safety inventories and extra capacity, which go against the efficiency goals of lean management. On the opposite side, the quick identification of problems and solutions and the ability to produce and deliver in a flexible way are all key elements related to lean, and are also factors that can help a firm adapt rapidly to changes in demand or supply, taking advantage of the opportunities brought by change and avoiding potentially costly mistakes.

Given these considerations, the present work inserts itself in the research line investigating the effect of lean adoption on the financial performance of firms. But more precisely, the work wants to focus on investigating the still largely uncharted matter of the impact on resilient performance. The research purpose is thus double: first, to search for confirmation of the fact that lean adoption leads to a superior financial performance, not only in situations of stability but also in situations characterized by high variability. And secondly, to investigate whether lean adoption can have a moderating effect on the negative performance impact generated by periods of high variability in business performance. In addition, some considerations are made regarding the impact that different levels of lean adoption may entail. The financial performance, used as a proxy to measure resilience, will be measured through indicators of performance: ROA, ROS, ROI.

The work is structured in the following way: Chapter 1 presents a general overview of the lean management philosophy, describing the five core principles that drive lean thinking, and explaining the different sets of techniques commonly employed for the purpose of lean transformations.

Chapter 2 then opens with a brief review of the literature findings regarding the relationship between lean adoption and firm performance. And while literature seems to agree on the beneficial impact of lean adoption on both operational and financial performance, there still appears to be uncertainty regarding whether these results are valid limitedly to stable environments or can be extended to firms facing situations of disruptions. This work thus attempts to investigate the possible connections between lean adoption and the concept of resilience, providing a definition of the concept of resilience, of its related capabilities, and an overview of the possible conceptual linkages among lean and resilience, through a review of the literature contributions on the topic.

To search answers, two different empirical analysis were then conducted. The starting point for these analysis was a database, containing information about a sample of Italian manufacturing firms derived from two sources, a survey and the AIDA database. In chapter 3 the sample is presented, providing graphical analysis of its main demographic, organizational and lean-related features. A preliminary analysis is then conducted to determine the presence of periods of disruption or turbulence.

The data is then employed in the following two chapters to perform two different analysis. In chapter 4 a first analysis is conducted employing T-tests. Firms are divided in four categories, depending on whether or not they were lean adopters and on whether or not they experienced periods of turbulence, and their performance is evaluated through the mean values of five performance indicators. The difference among the means is tested for significance through a t-test, to assess the presence of a significant positive difference.

Chapter 5 instead presents an investigation through OLS multiple regressions. Based again on the database available, a series of dependent and independent variables is defined, the models are presented and the results of the statistical analysis are reported. The purpose of this final analysis is to measure whether, at firm level, not only can lean adoption be linked to an improved business performance, but also whether it can be linked to a moderating effect of the negative influence on performance generated by a highly turbulent period.

The work concludes with a discussion of the results observed in Chapters 4 and 5, highlighting also the limitations present in the study and suggesting possibilities for future research.

CHAPTER 1

LEAN MANAGEMENT: PRINCIPLES AND TECHNIQUES

1.1 – Lean management: origins and definition

1.1.1 - The origins of lean management

For a large part of the XX century, mass production was considered to be the most efficient manufacturing system. This production system had developed first and significantly in Ford in the 1910s, and was based on large scale production of mostly standardized products. The system had been rendered possible by the introduction of innovations such as the moving assembly line, and it was further improved over the years with the introduction of managerial systems such as those devised by Alfred Sloan at General Motors (Womack et al., 1990). Mass production then spread successfully throughout the US, outside the automotive sector, and eventually reached Europe as well. With consumerism on the rise, it became the dominant system, since it allowed to satisfy the demand for high volumes of standard products at low prices.

However, in the second half of the century a different production system started to emerge, and progressively gained relevance throughout the decades because of its ability to provide more flexibility: the method of *lean production*. What made this new method relevant was that it wasn't simply a variation on the theme of mass production, but rather a completely new way of approaching the management of production and of the whole firm.

The origin of lean production is widely recognized in Japanese automotive company Toyota, which had been facing a situation of distress since the 1950s, caused both by the aftermath of World War II and by the inability for Japanese companies to implement mass production systems (Holweg, 2007). In fact, the Japanese market, and specifically the automotive sector, was characterized by features that distinguished it significantly from western markets (Womack et al., 1990): first of all, the domestic market was small and highly fragmented, which made mass production unsuitable since economies of scale could not be reached. Secondly, the different cultural background required to establish a different relationship with the work force: employees had a stronger contractual power compared to their Western counterparts, which meant that they could not be treated as an interchangeable element. And finally, there was a high degree of competition coming from Western companies, which in addition employed technologies that were unavailable to Japanese companies.

Given this situation, and the need to find a solution to its crisis, in the 1950s Toyota under the guide of Taiichi Ohno began to develop a different strategy instead of implementing the traditional mass production. In the following decades, the company gradually introduced innovations in their manufacturing and management practices which progressively allowed to reduce inventories, improve operational flexibility and increase quality (Holweg, 2007). The objective of this new strategy was to become able to produce wider ranges of products, in smaller batches and without increasing costs. The set of techniques and innovations employed would be referred to as the Toyota Production System, or TPS, and to this day is still considered the blueprint for companies who want to introduce a lean transformation in their operations.

The term *lean* actually only emerged and gained popularity later, in the 1990s, following the publication of the book *"The machine that changed the world"* (Womack et al., 1990), in which the authors performed a benchmark analysis of production systems in the automobile industry, showing the superior performance in terms of quality and efficiency of lean organisations when compared with organisations employing the traditional systems.

1.1.2 – Defining lean

Having seen briefly its origins, it still remains to clarify what the term concretely represents: and defining *lean* is not straightforward, because it's an extremely wide concept, which comprehends production techniques, managerial approaches and an entirely unique philosophy. In its simplest possible definition, lean management is about "doing more with less" (Bicheno and Holweg, 2016, p.1): in fact, the core idea of lean management is maximizing the value provided to customers while at the same time minimizing the resources used throughout the value stream, eliminating or reducing any source of waste in terms of materials, work and time (Womack and Jones, 2003).

Given the purpose of eliminating wastes of resources, the first applications of lean systems were mostly focused on manufacturing and production activities, and on specific sets of tools that could be employed. These practical elements, which comprise the so-called *TPS house*, usually represent the first step in undertaking a lean transformation, but it should however be underlined that lean is more than a set of tools for production: the mere introduction of these techniques as isolated improvements doesn't reflect the core idea of lean. Lean management is a philosophy, and as such it requires to embrace a new paradigm for how processes and issues within the firm are addressed, where the customer needs and the value created are placed at the core. In order to produce concrete results, the transformation must involve the entire company and all its functions (Womack and Jones, 2003): from design to distribution, each activity needs to be analysed and improved to bring a concrete change that will remain sustainable over time.

In relation to this point, a frequent misconception is that lean techniques represent simple cost-cutting tools. This is however incorrect: while it's true that lean aims at eliminating wasteful activities, its ultimate purpose is to obtain freed-up resources to be employed for stimulating growth and pursuing new projects, which can help increase the company's profitability over time and in a sustainable way (Womack and Jones, 2003).

Beyond waste reduction, another relevant aspect of lean is its consideration for the human dimension of the organisations. Differently from mass production approach, where workers are treated as mostly interchangeable parts, the lean approach encourages respect for them and treats them as thinking people (Bicheno and Holweg, 2016). The active involvement of the staff at every level is a pillar of lean: systems of job rotation and job enrichment are encouraged, as are team-work activities. The purpose is to increase the responsibilities of people in the organisation, in order to improve their sense of engagement (Slack et al., 2016). Another aspect on which management should focus is improving communication at every level, not only to ensure involvement, but also because the expertise of the staff is a key element to identify wasteful activities and developing creative improvements.

Finally, a fundamental aspect of lean is the idea of continuous improvement, or *kaizen*. In fact, the lean philosophy does not presume to be able to find the one-best-way of performing a certain task, but instead sees the improvement process as a series of small incremental actions carried out over time (Slack et al., 2016). Lean is a dynamic system, that requires to works in repetitive processes, within which mistakes can be seen not as issues to be avoided at all costs but as opportunities to improve (Bicheno and Holweg, 2016). The important aspect is not the entity of the improvements introduced, but rather the continuity of the process and the commitment over time.

1.1.3 - Lean and the concept of waste

To understand *lean* it's fundamental to understand the concept of waste, or more precisely of what the Japanese call *Muda.* As previously mentioned, at the core of lean management lies the objective of maximizing value while minimizing the resources used: a process is *lean* only if it can reduce the raw materials, time and human effort required to produce a product or service, while at the same time increasingly provide value to its customers (Womack and Jones, 2003). *Muda*, in simple terms, is any usage of resources that the customer won't be willing to pay for, because it does not add any value to the final product or service. Identifying the *muda*, and subsequently introducing tools and innovations to eliminate it, is at the core of any lean transformation.

According to Toyota executive Taiichi Ohno there can be seven types of *Muda*, which are potentially present not only in manufacturing but in any type of activity in a firm (Bicheno and Holweg, 2016; Hicks, 2007):

- Overproduction: the waste generated by production that is excessive compared to current demand, either because it's produced in an excessive quantity or because it's produced before receiving the orders.
- Waiting: the waste of time associated to delays or bottlenecks within the processes, which cause machines or operators to lie idle while waiting for work, and prevents from achieving a smooth flow.
- Motion: waste of working time associated with excessive movements of an operator or a machine, generally caused by a poor workplace arrangement or by excessive inventory in the processes. It can also refer to the excessive movement of information or decisions.
- Transportation: waste of resources associated to unnecessary movement of raw materials, work in progress or products within the organization. Transportation could cause additional waste in terms of damages to the products.
- Over processing: waste generated by performing a task with inappropriate instruments or in a way that includes unnecessary steps. It can also refer to excessive processing or handling such as those associated to excessive inventory.
- Inventory: waste of resources generated by keeping products, work in progress and raw materials in storage in superior amounts to those required to satisfy demand. The concept can also apply to inventories of customers or information.
- Defects: waste associated with errors in the processes, which lead to producing goods or services that ultimately have to be either reworked or thrown away.

In addition to *muda*, two other categories of waste can be identified. The first is *Mura*, which can be interpreted as the waste created by a lack of consistency in the activities. The existence of *Mura* may result in an excessive workload in certain periods, that will create operational problems in terms of speed and dependability. The second is *Muri*, which represents the waste generated by overburdening machinery or people in certain processes, usually because of failures to plan sequencing and scheduling in an effective manner (Slack et al., 2016). The three kinds of waste are all strictly interlinked, and both *Mura* and *Muri* contribute to the creation of *Muda*.

Firms which don't adopt lean may never see all the waste present in their operations, and may prefer to adopt inventory as a solution to increase their flexibility, instead of actively solving the operational issues they suffer from. Instead, if a company decides to pursue a lean transformation it will have to search and identify the waste in its activities, because understanding where the main shortcomings occur is the first step to develop improvement actions. Moreover, understanding the source of waste will allow not only to reduce it in the present, but also to prevent it in the future.

1.2 – The five lean principles

The lean philosophy can also be described through five guiding principles, which were derived from the observation of the first lean applications in firms, most importantly in the Toyota Production System. These principles were defined and theorized by Womack and Jones in their book *Lean Thinking* (1996), in order to provide a framework for firms who want to pursue a lean transformation. While the principles were originally thought in relation to manufacturing firms, they can be applied in the service industry as well (Piercy and Rich, 2009).

1 - Specify value

Before undertaking any lean transformation, a firm must identify clearly the value of its products or services, and define the value proposition it intends to offer. Traditionally, firms may approach the matter of value creation from an internal perspective, focusing on the improvement of their efficiency through innovations, or on increasing short-term profits through cost-cutting. However, building efficient processes won't translate into value-creation unless the offering reflects the needs of the customers (Womack and Jones, 2003).

Therefore, in the lean approach the value propositions must be defined in function of the customers, and ultimately focus on understanding and satisfying their needs. Value is in fact defined as “a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific time” (Womack and Jones., 2003, p.16). A lean firm must therefore clearly understand what the customer expects, when he expects it and what price he’s willing to pay for it, and then define the features of its product or service offered based on this. Consequently, the processes will also have to be revised, reducing or eliminating all the activities that don’t add value in the eyes of the customer.

In addition, this first principle influences the way in which lean firms should be organized: by adopting a customer-driven approach, the focus of the firm should move to the products. Instead of maintaining separate and independent functions, a lean organization should focus on optimizing the entire series of activities connected in the value creation for each different product or product family, for example through the introduction of product teams (Womack and Jones, 2003).

2 - Mapping the value stream

Once a company defines the value of its offering, it will have to identify all the activities within its processes that contribute to the creation of this value. This step is fundamental in order to plan well-thought improvements, that guarantee the success of a lean transformation in the long term (Rother and Shook, 2003). To perform this step, firms should look at their value stream, which is defined as “the set of all the specific actions required to bring a specific product […] in the hands of the customer” (Womack and Jones, 2003, p.19). The value stream includes not only the strictly manufacturing activities, that physically transform raw materials into a finished product or service, but also all the related activities, such as the management of information required to take orders and to plan deliveries, and the problem-solving activities related to the design and engineering of the product or service, from concept to launch.

The process of analysing the value stream is called mapping, because it requires to draw an actual, comprehensive, map of the processes. A first map should be drawn, for each product or product family, to represent the *current-state* of operations: this will allow to see clearly every process in the production path from start to finish, which is a necessary step to uncover the activities that represent a source of waste (Rother and Shook, 2003). Mapping requires to perform a *Gemba walk*, which means physically going to the plant or workspace, the place where value creation concretely happens. The purpose of the *Gemba walk* is observing the production activities, understanding how they work and noting down all the information acquired about the activities and the flows of materials and information, to uncover problems and waste (Slack et al., 2016).

When analysing the *current-state* of operations, companies will find three categories of activities (Womack and Jones, 2003):

- Value-adding activities: activities that are necessary and add value to the output, because they concretely change and transform the product.
- Type One *muda*: activities that don't add value to the final output, but are currently necessary to the process. While they can't be eliminated, they should be optimized and reduced.
- Type Two *muda:* activities that don't add value to the final output, and are not necessary to the process. They represent pure waste of resources and should be eliminated.

Once the wasteful activities are identified, improvements can be introduced. At the end of the process, a *future-state* map should be drawn, which will include all the innovations introduced to achieve a leaner value stream (Rother and Shook, 2003).

It should be added that the value stream of a product usually goes beyond the borders of a single organization, involving a series of connected firms and facilities both upstream and downstream (Womack and Jones, 2003). *Muda* could be present in the activities of all these related organisations, or even worse it could be a result of wasteful duplications of certain activities, but unless organisation go beyond the traditional boundaries of a firm and focus on the entire set of activities, they may never identify the waste.

3 - Flow

The third principle focuses on a fundamental shift in the traditional idea of how a firm should be organized. In lean processes, parts should not follow the traditional batch-and-queue rhythm, where parts are processed in batches and move accordingly to the schedules of each working station. On the opposite, each part or product should flow almost seamlessly from one station to the next, without unnecessary stoppages or waits in inventories along the line (Rother and Shook, 2003). This layout is also called "single-piece" flow production, since the objective is to have items that are processed one at a time.

In order to attain it, a rethinking of traditional work practices and instruments may be necessary. Production processes could for example be organized in small cells, one for each product or product family, within which the operators work following a line layout, rather than in larger but separated workstations. This new organization will also require a rethinking of the tools employed, for example switching to smaller machines, and in addition techniques could be introduced to minimize the avoidable *muda* related to excessive movement, waiting or mistake correction (Womack and Jones, 2003): some common examples are *Poka Yoke*, SMED techniques, or the 5S technique, which will be described further in the chapter.

However, flow can't always be implemented, as it requires stations to be placed next to each other and activities with similar processing times. Moreover, the idea of flow may appear counterintuitive to firms used to batch production. Nonetheless, where it can be implemented this structure of production grants the production processes a much greater flexibility than traditional mass production allows, making firms more responsive to their customer needs. In addition to this, relying less on inventories will expose the issues within the processes, and will encourage to solve these problems in order to make the processes more efficient (Slack et al., 2016).

Finally, the principle of flow should not be restricted to the manufacturing function, but it should be extended to the other functions of the company. For example, the design activity could achieve flow through the introduction of dedicated product teams, the sales function could benefit from the synchronization of the sales rate with the production rate, and other improvements could be introduced in sourcing activities or delivery activities (Womack and Jones, 2003). The objective is to eliminate traditional fixed barriers within functions and achieve a situation where every activity along the value chain is efficient and connected to the others.

4 - Pull

As previously mentioned, one type of *muda* that can occur in a company is overproduction, which can occur frequently in firms adopting a traditional mass production. These firms operate according to a push logic, whereby they try to anticipate demand relying on forecasts. Items are produced before receiving the orders, and are then either pushed on the customers or stored in inventories. Moreover, MRP systems plan the activity for each process, and thus each process works at its own pre-scheduled pace, independently from other processes and from downstream demand (Rother and Shook, 2003). While this system allows to have stability in operations, the unreliability of forecasts may lead to overproduction.

Lean therefore adopts an opposite approach, the pull approach, which is defined as the principle that “no one upstream should produce a good or a service until the customer downstream asks for it” (Womack and Jones., 2003, p.67). In pull processes each activity should pull the next, and production itself should only be activated by an order from the downstream customer, which can be either an internal customer, such as one of the other stations, or an external customer.

The benefits of adopting a pull system are many (Hopp and Spearman., 2004): the work-in-progress is monitored and reduced, which in turn contributes to reducing production cycle times. The achievement of flow is facilitated, as inventories are reduced. Moreover, the reduction of inventories allows to expose hidden problems in operations, which can thus be addressed and solved. And finally, since the system becomes more sensitive to disruptions, the need for rapid defect detection and reduction increases, and over time leads to improved quality.

Employing the pull mechanism is rendered possible by the improvements brought with the first three principles, which allow to reduce the time required to bring the product to the customer. However, it’s difficult to perfectly coordinate demand and offer, and in addition continuous flow is not always possible: therefore, to solve these coordination issues some inventories between different activities will be necessary, even if minimized (Slack et al., 2016). Organisations may employ *supermarket systems*, small inventories which act as buffers between activities that work at a different rate, or between production and demand. A withdrawal from the supermarket also represents a signal for upstream production to re-start: jn fact, usually this system is adopted in coordination to *kanban* systems, visual tools that signal when new parts or products need to be produced (Rother and Shook, 2003).

5 – Perfection

The final principle of lean is the principle of perfection. However, this principle should not be interpreted as the idea that it’s possible to reach an optimal situation, because the lean philosophy doesn’t believe that perfection can ever be reached. While traditional approaches aim for example at cost minimization, the lean approach doesn’t plan to reach a one-best-way, but nonetheless believes that it should continue to strive for it.

The first introduction of lean in a company's operations represents a *kaikaku,* a radical change, a fundamental shift in paradigm that should be able to bring some visible improvements in the short-term. But these radical innovations should only represent the first step: change is a dynamic process, and any innovation should be followed by a re-evaluation of what is currently being done and of how it could be improved. In addition to radical improvement, lean companies should strive for *kaizen*, the continuous and incremental improvement. And while perfection may be unattainable, it "provides inspiration and direction essential to making progress along the path" of lean transformation (Womack and Jones, 2003, p.94).

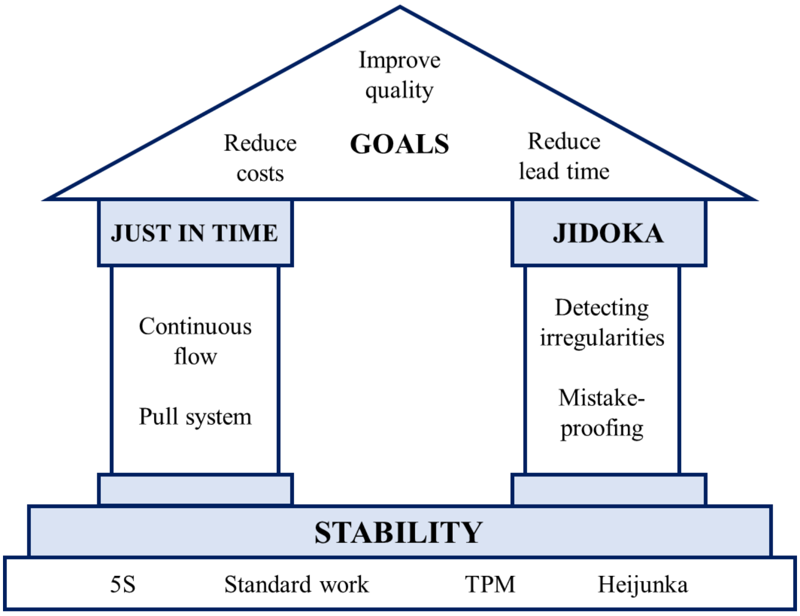
To achieve this in practice, companies should first commit to applying the first four principles. Once they achieve this, managers will find themselves in front of a wide range of possible projects to focus on: therefore they should prioritize which issues and wastes must be addressed first, through the technique of policy deployment, and set specific goals and timetables (Womack and Jones, 2003). Finally, even though the lean transformation generally starts at production, to truly pursue perfection it will have to spread over time to the entire organization, involving every activity and employee, and eventually beyond the organization, involving partners upstream and downstream.

1.3 – Lean techniques: the Toyota Production System

While they are all guided by the same principles and values, lean transformations do not occur in the same way in each organization: each transformation needs to be unique and tailored to the needs and objectives of the specific company. However, there are some frameworks intended to guide lean transformation, the most famous of which is the TPS House, based on the Toyota Production System (Figure 1.1). This framework identifies three fundamental goals for a lean transformation (Bicheno and Holweg, 2016): increasing the quality of the products created, reducing the production costs, and minimizing the lead time, which is the time between an order being received and the customer concretely receiving the product or service.

In practice, there are a variety of different techniques that can be employed to achieve these goals. Once established the three macro-objectives of lean, the techniques can be divided in three categories, which represent the foundations and pillars of the "house": *Stability* techniques, *Just-in-time* techniques and *Jidoka* techniques.

Figure 1.1 – The TPS House



Source: personal elaboration from Lean Enterprise Institute (2006)

1.3.1 – The foundation: Stability techniques

To ensure the success of a lean transformation, we need to introduce at the basis techniques that allow to obtain efficient processes that will remain stable over time. It is necessary to reduce any fluctuations in production times that may be caused by frequent breakdowns of machinery, difficulties for the operators to access the tools needed, lack of clear standard procedures or variations in the production volumes. Some popular techniques are employed for this purpose of stability.

5S

5S is a popular tool, generally employed at the beginning of a lean transformation, aimed at reorganizing the workspaces in order to make them cleaner and better organized. It’s a simple but effective tool, since its visual nature allows to produce visible improvements for the workers, which can represent a strong form of motivation. Moreover, this first step allows to uncover some of the present *muda* and to improve productivity, since working in a well-organized environment allows operators to lose less time in unnecessary motion. Applying this technique also increases the sense of engagement of the workers, who are involved and tend to develop a sense of ownership towards the workspace: the method goes beyond the simple act of tidying up a space, and aims at bringing a change in attitude in the workers (Bianchi, 2010). However, it’s important to underline that it only represents a first step in a lean transformation, that should be repeated systematically over time and accompanied by other techniques.

The "5S" indicate the five steps of which the method is composed (Bicheno and Holweg, 2009; Bianchi, 2010):

1. Sort (*Seiri*): the first step requires analysing the tools and instruments in the workplace, and eliminating those that are not functional or needed. The decisions regarding what is useful and what isn't should be based on criteria decided in accordance with the work team.
2. Straighten (*Seiton*): the second step consists in a reorganization of the space, in a way that allows instruments to be easily found and reached when needed. The reorganization should take advantage of visual tools, for example employing shadow boards or colour coding, since the organization should be clear and evident to anyone who accesses the workspace.
3. Shine (*Seiso*): the third step requires to clean the re-organized work environment, and to keep it tidy on an ongoing basis. Defining a simple tidying routine allows to improve efficiency, quality and safety, and in addition it allows to regularly check for abnormalities in the workspace.
4. Standardize (*Seiketsu*): this step is about ensuring that the results obtained in the first three steps are sustained over time, developing standards and guidelines for the first 3S.
5. Sustaining (*Shitsuke*): the final step is about sustaining the improvements introduced, by developing a commitment 5S and turning them into a habit. Regular audits should be planned and conducted, both internally and externally. The 5S method should become an integral part of the daily life in the workplace, and not remain an isolated, one-shot activity.

Standard work

This tool of the Toyota Production System requires to define the best method to perform an activity, given the available equipment, people and materials. In practice, it occurs through the elaboration of standard operating procedures, which then need to be communicated and displayed in a clear and visual way. For the purpose of this technique, it is important that operators be involved in the writing of the job instructions, so that they can fully understand the various aspects of their work and why they must be performed in a certain way.

Standard work is aimed at building reliable processes, that are effective and consistent over time. In addition, defining standard operating procedure procedures is the basis for *kaizen*, because it allows to continuously find aspects of performing a certain activity which could be further improved. In fact, the standard operating procedure shouldn't be perceived as rigid and static, but rather as a form of guidance, which can be changed and updated if improvements are found (Bicheno and Holweg, 2016).

Total productive maintenance

Differently from the traditional idea of maintenance, according to which it is a task to be carried out by expert engineers and technicians, the Total Productive Maintenance approach requires also for the operators to play an active role. According to TPM, regular employees should be involved in routine maintenance activities, which in addition should be carried out on a daily basis in order to keep equipment in a good state and prolong its life cycle (Slack et al., 2016). Concretely, this purpose can be attained for example by defining standard practices for the employees which include daily maintenance routines, or through problem-solving activities in small teams aimed at increasing equipment effectiveness (McCarthy and Rich, 2015).

The effect of applying TPM is an enlargement of the responsibilities of the employees, which increases their motivation, but also the possibility to free up experts and specialists so that they can focus on more complex tasks. Moreover, introducing a set of TPM techniques increases the reliability of the processes, reducing the risk of process failures and the possible negative consequences in terms of costly disruptions and reputational damages (Bicheno and Holweg, 2016).

Heijunka

The practice of levelled scheduling, or *heijunka*, is aimed at reducing the variability in processes, which is a cause of disruption and can be a significant source of waste in terms of inventory and quality. Concretely, this technique requires to maintain a balance of both the quantity and the mix of production over time. Instead of producing in large batches but infrequent intervals, the *heijunka* approach requires to schedule the production of the different products in smaller batches and on a regular basis (Slack et al., 2016). Moreover, the production schedules obtained through this technique need to be reviewed frequently, to ensure that they remain in line with customer demand (Lean Enterprise Institute, 2020).

1.3.2 – The first pillar: Just in time

Differently from mass production, where products are produced according to fixed schedules, based on forecasts and not on actual demand, lean production adopts a pull approach, whereby products are produced only when requested, according to a Just-in-Time logic. Firms need to provide the right quantity of goods, at the right place and at the right time, all while reducing inventories, and achieving this challenging goal requires a set of techniques aimed at making processes leaner.

Cell layout

In order to work with a just-in-time rhythm, operations must achieve the lean principle of flow, and the traditional functional layout is not an adequate solution: activities are carried out independently by separated workstations, the system usually requires working in batches, and the consequence of this layout is that a significant amount of wasteful transportation occurs. A better solution for the purpose of flow is to have activities organized in a sequence, without unnecessary stoppages or transportation.

This is generally obtained through the introduction of manufacturing cells, which can be defined as a type of layout where each step in a process is placed close to each other, in a sequential line. Within the cell, operators work as a team, processing parts in a one-piece-flow and performing all the necessary activities within the cell's borders (Slack et al., 2016). The introduction of this layout allows to reduce buffer inventories, gives more opportunities for job rotation or job enlargement, and allows to quickly identify quality issues. Moreover, since products are processed in a one-piece-flow and never stop, this layout allows to significantly reduce lead time (Bicheno and Holweg, 2016).

Line balancing

Within a cell, the process should flow smoothly, without the product stopping or operators remaining idle as they wait for work, and this is only possible if the workload within the line is balanced (Womack and Jones, 2003). The reason behind this is that the cycle time of a process, which is the time required for one unit to go through the production process, will be determined by the process' bottleneck, which is the slowest of the activities. When the bottleneck activity requires significantly more time than the other activities in the cell, the process cannot run smoothly.

Therefore, the single tasks to be performed within a cell should be analysed and measured, and based on the data acquired and on the cycle time that the process aims to achieve, tasks should be redistributed in a more balanced way between the operators, so that each operator is processing units at a similar rate and bottlenecks are avoided (Bicheno and Holweg, 2016).

Right sizing

In traditional functional layouts firms tend to employ large, technologically advanced machines. These machines are efficient in mass production, because they allow to obtain economies of scale, but they also impose several constraints on the flexibility of operations: they have long and complex set-up changes, they can't be moved easily, and maintenance requires advanced technical skills.

Thus, in lean manufacturing, and particularly when a cell organization is introduced, it would be more efficient to employ several machines of a smaller size (Womack and Jones, 2003). A strong benefit of this change in equipment is that it allows to process different products simultaneously, granting more flexibility to operations, and making the process less vulnerable to being slowed down by a bottleneck or disrupted by machine breakdowns (Slack et al., 2009). In addition, these machines are generally easier to set-up and to maintain.

SMED

This acronym stands for "Single Minute Exchange of Dies", and represents a set of techniques introduced originally by Japanese engineer Shigeo Shingo at Toyota, and aimed at reducing the set-up time of machines (Womack and Jones, 2003). SMED techniques allow for example to change moulds or dies in quicker way, and the reason why a reduction of changeover times is important is that it allows to process smaller batches or even one piece at a time, thus improving the flow.

To implement these techniques, the first step consists in measuring and recording the current set-up times associated to each activity. The activities should then be separated in internal activities, which can only be performed by stopping the machine, and external activities, which can be performed while the machine is running. Based on the information gathered some improvements should be introduced, aimed mainly at minimising the internal activities, either by converting them into external activities or through engineering to make them more efficient. The improvements introduced should also be aimed at reducing the variation in set-up times, to make the changeover routine not only quicker but also more regular (Slack et al., 2016).

Kanban

As previously mentioned, to introduce a pull system firms frequently employ small controlled inventories, called *supermarkets,* kept between processes. These systems are usually accompanied by the use of *kanban*, a popular set of signalling techniques (Rother et al., 2009).

There are three principal kinds of *kanban* (Bicheno and Holweg, 2016): production, move and vendor *kanbans*. The most common are production *kanbans*, and particularly the method of single cards. This system is comprised of cards placed along the physical inventories in processes, such as the containers, which contain clear information about the component they are associated with. When new components are needed, *kanban* cards are sent to the upstream workstation, and this signal represents an authorization to start production. Production *kanbans* can also be sent in electronic form, or they can take different visual forms, such as vacant squares on the shop floor or empty spaces: all of these methods represent the same type of signal for production.

The other two other types of *kanban* instead do not trigger production, but delivery. Specifically, move *kanbans* signal the necessity to deliver a component or a work-in-process to a specific stage of production, while vendor *kanbans* signal a necessary delivery to external customers.

1.3.3 – The second pillar: Jidoka

The second pillar of lean, Jidoka, focuses on improving the quality of the products and services created. In the lean approach, to obtain this it’s necessary to minimize the probability of defects occurring in the first place, which can only be achieved by building better processes.

The concept of Jidoka is based on autonomation, the practice of employing automated machines with a human-like intelligence. These machines should have the ability to detect defects in the production process, and to react to these abnormalities by stopping the production and signalling operators the need to intervene (Womack and Jones, 2003). For these purposes, the most common techniques employed are *Andon* and *Poka-Yoke*.

Andon

Andon systems are visual tools employed to avoid the propagation of a defect along the production line. The first element in a typical *Andon* is a cord placed along the production line, which can be pulled by the operators when they spot an issue. The cord could be substituted by a button or by automated sensors, and its purpose is to trigger a visual signal, that will indicate when a problem occurred and in which station (Lean Enterprise Institute, 2020).

The triggered signal could be represented either by a light above the workstation, or appear on a separate element, the *Andon board,* a display that provides information about the current status of production (Womack and Jones, 2003). The visual signal will allow for operators to be alerted and go help fix the issue. If necessary, for example in situations where the issue can't be solved rapidly, the *Andon* system can be triggered to signal the necessity to stop the line.

Poka-yoke

Poka-yoke represents a series of devices and mechanisms employed in process design to prevent defects that can occur because of human mistakes. Common defects caused by human errors in the processes are for examples instances in which an operator uses the wrong component, or installs it in the wrong way (Slack et al., 2016). *Poka-yoke* are generally quite inexpensive devices, whose function is to stop a particular action or to warn the operator when a mistake occurs. There are three main categories of devices (Bicheno and Holweg, 2016):

- Contact *poka-yoke*: for example, spaces of a fixed shape or diameter through which only products of the right dimension can pass.
- Fixed *poka-yoke*: designs that clearly underline whether a part is missing.
- Motion step *poka-yoke*: designs or checklists that ensure that the necessary steps and procedure are followed.

Despite their simplicity, they allow to prevent simple mistakes from becoming defects in final products and services. This is turn is translated in great savings, because it prevents the company from having to undertake costly activities of rework and defect correction.

1.4 – Lean beyond manufacturing

The techniques described in the previous paragraph were all focused on improving the production processes, and in reality most firms have a tendency to apply lean limitedly to manufacturing activities. However, lean developed as a management system, which was meant to involve the entire firm and bring not only gains in operational efficiency, but also to have an impact on the company's strategy (Furlan, 2018). To obtain significant and sustainable results, a lean transformation should go beyond manufacturing activities: it's therefore worth to focus in the last pages of this chapter on some possible applications of the lean philosophy to other key activities performed within the firm.

Moreover, it's worth to mention that the ultimate goal of lean is to have a firm go even beyond its own organizational boundaries, and look at the entire set of activities that comprise the value stream of each product. The mechanism necessary to achieve this is the creation of a lean enterprise, a voluntary cooperation with the other firms involved along the value stream, within which firms communicate with transparency and with the common purpose of eliminating the muda. However, this is not an easy task, as it requires a rethinking of the traditional relations between firms (Womack and Jones, 2003).

1.4.1 – Lean in product development

The traditional approach to product development is composed of sequential decisions taken by people working in separate functions, with each department focused on its specific needs. What often occurs because of this approach is that the lack of communications between departments leads to a long development process, as the design requires reworks or modifications because of issues or incompatibilities that emerge during the process.

From a lean point of view, this approach presents hidden *muda:* examples include the defects in the projects that emerge during the process, the waiting that occurs between separate functions, and the over-processing related to each project being analysed several times by different departments (Bicheno and Holweg, 2016). The waste in design activities is just as relevant as the waste in manufacturing, and needs to be addressed to improve the organizational efficiency.

The lean approach therefore aims at creating cross-functional product teams that can possess all the knowledge and skills necessary to bring a certain product or service from the first design to production. Gathering in the same product team all the people responsible for the design, for the engineering and for the materials selection guarantees greater communication (Womack and Jones, 2003), which allows to prevent incompatibilities from occurring in the first place.

Overall, this practice allows to significantly reduce both the time and the work necessary for product development. This will bring improvements from three points of view (Bicheno and Holweg, 2016): first of all, costs will be reduced as a result of less reworks and more efficient sourcing of materials. Secondly, speed will be increased, which in turn will translate in the ability to be more responsive to shifts in customers demand and needs. And finally, quality of the product or service will be improved, as defects are more likely to be identified before the launch.

1.4.2 - Lean in sales and marketing

As explained before, the lean approach places the customer at the core of its activities: the customer's needs are what drive not only product development, but production itself. Thus, in firms engaged in a lean transformation the order-taking activity of sales should not be an activity that occurs in isolation, focused either on pushing excess products or on expediting orders to meet demand. The goal is to have fully linked processes, from the raw materials to the final delivery.

For this purpose, in a lean firm the sales team should be actively involved in the different product teams. To achieve flow, order-taking can't be independent from production scheduling: instead, orders must be planned with a clear idea of the production system's capacity and schedule (Womack and Jones, 2003). To achieve this concretely, it's fundamental for firms to become familiar with the concept of takt time, which is the ratio between the demand rate and the available working time (Rother and Shook, 2009): the concept of takt time should guide the production pace, in order to make it connected to the demand rate.

Moreover, a lean approach to marketing requires to overcome the traditional idea of pushing the products at any means necessary, often through temporary promotions or through incentives systems for the sales force. These activities may result in a temporary increase in sales, but ultimately won't lead to sustainable growth in terms profits or in terms of customer base (Womack and Jones, 2003). What could instead lead to sustainable growth is developing a more rational approach to sales: companies should employ systems to identify and evaluate potential customers, in order to determine the most promising targets, on which they should focus energy and resources (Webb et al., 2018).

Finally, just as wasteful activities should be eliminated from production processes, they should also be removed from sales and marketing: any marketing activity that is perceived as unwanted by the customer, or that utilises resources without actually leading to closed sales, should be revised or when possible eliminated (Webb et al., 2018).

1.4.3 - Lean accounting

An application of the lean philosophy to accounting may not be appear as an immediate concept. In fact, some benefits brought by lean transformations may actually have a short-term negative effect in accounting terms, like for example inventory reductions, which are translated in lower assets in accounting (Bicheno and Holweg, 2016). Moreover, traditional financial accounting systems are employed for tax purposes and to communicate information to shareholders, but are not meant to be used for decision-making. Lean accounting wants to represent an alternative to financial accounting systems, not meant to replace them but rather to be used alongside them, for the purpose of gathering and displaying information in a useful way that can help managers make better operational decisions.

The accounting systems commonly employed are based on cost assumptions, allocated to different functions based on pre-determined criteria such as for example work hours. What lean accounting wants to introduce is instead a system with a product-based approach: costs must be assigned, when possible, to the products or product families for which they were incurred. The purpose of this is to show the members active in a value stream whether their work is concretely creating value (Womack and Jones, 2003). It should be noted that this is a step of lean transformation that should be introduced at a more advanced stage, as it will be more effective after a previous reorganization of operations in terms of product families.

A reporting tool that can be employed for lean accounting is the box score, which is meant to include data and measures describing the operational performance of the activities along the value stream, and display it in a way that is comprehensible even to operators who don’t have an accounting background. Generally, it will contain three categories of information (Katko and Furlan, 2018):

- Measures of operational performance: lean accounting should focus on operational measures that can describe the performance of a firm’s processes. Depending on the aspect of performance that needs to be analysed, some of the most useful are flow measures, quality measures and productivity measures.

- Information regarding capacity: the way in which lean transformations create value is by freeing-up capacity, which can then be employed in more efficient ways by the firm. Thus, a lean accounting system should be able to identify and report both the capacity that is employed efficiently and the capacity that becomes available following operational improvements. Using capacity instead of standard costs allows to see in a more immediate way the concrete effects of possible operational decisions.
- Value-stream based financial records: in lean accounting, financial records should be organized around the concept of value-streams. Instead of being allocated to functions, both costs and cash flows should be referred to the products to which they are connected. This will make operational improvements more visible in financial terms, and will also make financial records easier to interpret.

CHAPTER 2

LITERATURE REVIEW

2.1 – Lean management and performance

Lean management literature is extensive and still growing, and it has developed significantly over the years focusing on several aspects of analysis. The different lean techniques and practices available have been thoroughly investigated, individually but also commonly grouping them in four bundles: just-in-time (JIT), total quality management (TQM), total preventive maintenance (TPM) and human resource management (HRM) (Shah & Ward, 2003). Moreover, many works have focused on understanding the impact of the adoption of lean management practices on a firm's performance, providing ample evidence on the benefits it can bring. On this topic, the works investigating the impact of lean practices on performance suggest that this effect tends to be greater with joint implementation of several lean practices (Cua et al., 2001; Shah & Ward, 2003), proving in addition the existence of complementarities among the different bundles of practices (Furlan et al., 2011).

Many works have considered the effect on operational performance, measuring the positive impact of lean practices implementation through indicators of quality, cost, speed (Shah & Ward, 2003) dependability (Belekoukias et al., 2014) and flexibility (Chavez et al., 2013; Dal Pont et al., 2008). In general these works agree on the existence of a positive relationship, although they underline that achieving improvements in operational performance is only possible through the extensive implementation of several practices (Losonci and Demeter, 2013).

Other works have instead focused on the relationship between the implementation of lean bundles and financial performance, finding evidence of a positive relation (Yang et al., 2011): in this area, Just-in-Time is found to improve profitability, measured through performance indicators such as ROA and ROS (Fullerton et al., 2003), and so are the other lean bundles TQM and TPM (Hofer et al., 2012). In fact, none of the lean bundles seems to be responsible for improvements in financial performance on its own, but rather when implemented jointly to other lean bundles (Galeazzo and Furlan, 2018).

Furthermore, in recent years literature has branched even further, and there has been an increased interest in studying whether and how lean management can be integrated with other managerial practices with different purposes, such as investigating the possible synergies among lean and green sets of practices (Garza-Reyes, 2015; Inman and Green, 2018) and the links between lean manufacturing and Industry 4.0 (Buer et al., 2018).

A different topic, that has however not yet been investigated extensively in literature, is whether the apparent positive impact of lean management adoption on performance is sustained even in situation of crisis or turbulence: in other words, whether a positive or negative relationship can be found between the adoption of lean management practices and the resilience of a firm in a situation of disruption or crisis. It's worth to mention that a few authors have addressed the issue of how contextual factors may moderate the positive impact of lean on performance, and among these some interesting observations have been made regarding the influence of dynamic environments, or in other words on the impact of operating in environments characterized by frequent, unpredictable disruptions and a high rate of variability. The results are however contrasting.

Some authors argue that, focusing on operational performance, lean management may be helpful in dealing with environmental dynamism, since the synchronization of operations and processes allows to be increase flexibility and adjust the production rapidly according to the changes in demand (Zubi et al., 2015). On the contrary, other authors believe that the effectiveness of lean management is reduced in unpredictable environments. Azadegan et al. (2013), when investigating the influence of environmental dynamism on the financial performance benefits brought by lean operations, find a negative relation: according to their study, the higher the levels of unpredictability in an environment, the more difficult it becomes for lean operations to synchronize the production processes and reduce inventories, which in turn reduces the effectives of lean operations and the related benefits. In fact, there seems to be a point of conflict related to production-focused lean practices, and in particular to inventory reductions: on this topic, it's been argued that strong inventory reductions may have negative implications on financial performance in industries characterized by higher rates of dynamism (Eroglu and Hofer, 2014).

However Azadegan et al. (2013) don't discard completely the positive effects of lean, since at the same time they find a positive interaction between environmental dynamism and the practices of lean purchasing: practices such as frequent information sharing with suppliers and collaborative problem solving help build a closer relationship with suppliers, which in turn can help resolve issues within the supply chain and face significant disruptions in customer demand, improving the performance of a company even in dynamic environments. It's suggested that a higher extent of lean practices implementation, that includes not only production-related practices but also transactional processes, can increase the sustainability of performance even in uncertain environments (Birkie and Trucco, 2017). It could be argued that this observation is in line with the opinion in literature that the joint implementation of several lean practices brings stronger performance benefits (Shah & Ward, 2003).

Before proceeding with any analysis, and considering this contrasting opinion in literature, it's worth to try and understand the reasons why, from a conceptual point of view, one could expect for the adoption of lean practices to have an enhancing or a damaging effect on the resilience of firms when they find themselves operating in turbulent environments.

2.2 - The concept of resilience

The previous paragraph mentions a concept, *resilience*, that while commonly used is not necessarily straightforward to understand. Therefore, while the concept of lean has been already discussed in the first chapter, it's worth to attempt to describe at this point how literature defines the concept of resilience. The concept is employed in multiple disciplines, from psychology to biology (Ponomarov and Holcomb, 2009), but for the purpose of this work it's important to understand its definition from a business management perspective. A general definition describes *resilience* as the ability of a system to recover rapidly from a disruption, either returning to its regular state (Carvalho et al., 2011), or to a new and more desirable state (Christopher and Peck, 2004). In other words, in enterprises and firms resilience represents the dynamic capability to respond and adapt to unexpected changes in the environment, which is attained through the development of flexible processes and the firm's ability to create and implement innovative solutions rapidly.

Being resilient and capable of adapting quickly to changes in the business environment is becoming an increasingly important attribute for firms today, because today's markets are turbulent and disruptions are becoming increasingly frequent (Lotfi and Saghiri, 2018). Disruptions can have different extents and sources, and a possible distinction can be made for example among internal disruptions, external disruptions and environmental disruptions (Christopher and Peck, 2004):

- Internal disruptions: disruptions related to everyday risks, relatively to the internal processes of a firm.
- External disruptions: disruptions originated in the supply chain, either on the demand side or on the supply side. Among these, disruptions related to demand uncertainty

have increased significantly in the last decades, since global competition has increased and product life cycles have become increasingly shorter (Sheffi and Rice, 2005).

- Environmental disruptions: disruptions generated by factors outside the firm's network, such as natural disasters, geopolitical conflicts, terrorism and pandemics. Recent examples can be found in the terrorist attack of 9/11 in 2001, in the tsunamis Asia in 2003, in the global financial crisis of 2008 (Purvis et al., 2016), and more recently in the 2020 pandemic.

In addition to disruptions having become more frequent, their effects are also amplified, since in today's economy supply chains have become complex, global and decentralized (Mohammaddust et al., 2017): they span beyond the borders of single countries and industries, becoming networks of interconnected firms located all over the globe. While this structure can bring many benefits in terms of cost efficiency, it also involves significant risks, since the negative consequences of a disruption can rapidly spread beyond the single company where the disruption occurs, and throughout its partners along the entire supply chain (Ponomarov and Holcomb, 2009). Therefore, while cost efficiency remains a priority, being resilient has become crucial for firms (Lotfi and Saghiri, 2018), and underestimating the possibility of disruptions to improve efficiency and reduce short-term costs can prove to be more expensive in the long run (Chopra and Sodhi, 2014).

Just as building efficiency requires the implementation of practices, such as those that comprise lean management, building resilience also requires the adoptions of certain practices. And while there isn't universal agreement in literature regarding which specific practices are more effective to obtain resilience in firms and in supply chains (Kamalahmadi and Parast, 2016), there are two key capabilities frequently associated with operational resilience: redundancy and flexibility (Sheffi and Rice, 2005).

Examples of redundancy-building practices include maintaining safety and strategic inventories, adopting multiple sourcing or backup suppliers, and maintaining extra capacity in the operations, either in terms of machines, labor or facilities (Purvis et al., 2016; Mohammaddust et al., 2017). However, while redundant practices can prove useful to respond rapidly to disruptions, in the absence of a disruption these redundancies represent a pure cost (Sheffi and Rice, 2005), and moreover they are not sufficient on their own to build resilience (Ambulkar et al. 2014). For this reason, flexibility, which reflects the ability of firms to reconfigure their resources to respond to external changes, is also considered to be a key capability for resilience: it allows to react quickly to unusual changes, and can also increase a firm's competitive advantage even in the absence of disruptions (Sheffi and Rice, 2005). Examples of flexible practices are flexible transportation (Purvis et al., 2016), a flexible supply base, and conversion flexibility in manufacturing, which allows to reconfigure rapidly production processes through the use of standard processes, multiple locations and multi-skilled workforce (Mohammaddust et al., 2017).

Other capabilities that are considered relevant include disruption orientation and network cooperation. Disruption orientation means that to be resilient firms should be concerned with detecting internal and external disruptions and with learning from past disruptive experiences, in order to develop adequate responses (Ambulkar et al. 2014). And beyond this, resiliency can also be enhanced through collaboration with supply chain partners: collaboration involves information sharing with partners, which in turn can help identify external risks in advance (Polyviou et al. 2019) and adapt rapidly to market turbulences (Pal et al., 2014). Finally, less tangible aspects such an organization's culture, the capabilities of its workers and the trust relationships built among workers are found to have an impact on resilience, particularly in the context of small and medium sized enterprises (Pal et al., 2014; Polyviou et al. 2019).

Therefore, to build resilience at firm level both anticipative and reactive capabilities are necessary: the first are aimed at preventing the disruptions, by detecting them early and building preemptive capabilities. The latter are instead focused on reacting to the disruptions, by adapting the operations to the changes, exploiting the potential opportunities created by the disruptions and sustaining the operations over time. Following this approach, and inferred from practices concretely employed by companies that mitigated negative disruptions, five core functions of operational resilience can be defined: sense, build, reconfigure, re-enhance and sustain (Table 2.1).

However, despite the growing interest in the literature around the topic of resilience, at the time there is very limited literature investigating whether the adoption of lean management is somehow related to the resilience of firms and their supply chains. Moreover, most works on the topic employ conceptual approaches, and there is therefore a lack of empirically-based analysis in literature; a possible reason stated for this is the difficulty in collecting data that can clearly express and reflect the resiliency of a firm (Birkie, 2016).

In addition, the few works addressing this topic present mixed opinions, leading to an apparent paradox regarding the nature of the relationship: according to literature, the practices that comprise lean management present both convergence and divergence points with the practices that are employed for the purpose of resilience (Ruiz-Benitez et al., 2019), which leads to the existence of both potential synergies and trade-offs among the so-called *lean paradigm* and *resilience paradigm* (Carvalho et al., 2011). To attempt to give a full picture on the topic, and understand why it's difficult to comprehend if lean management can concretely influence positively or negatively the resilience of a firm, in the remainder of the chapter these two conflicting points of view will be addressed. In the next section, the arguments in favor of the prevalence of a trade-off between the two paradigms are presented.

Table 2.1 - Operational resilience core functions and underlying practices

Core function	Purpose	Underlying practices
Sense	Practices that help a firm detect disruptions and build anticipative know-how	- Scanning the business environment regularly for signals of disruption - Establishing a plan for communication of incidents - Collecting promptly information regarding the incident
Build	Practices aimed at building capabilities to prevent or react to disruptions	- Undertaking regular crisis management exercises - Establishing multi-competence teams - Informing rapidly relevant functions of the firm - Assigning experienced people to handle supply disruptions - Effectively collaborating with external factors
Reconfigure	Practices aimed at adapting operations to changes	- Shifting demand across time, market, product - Identifying alternative suppliers - Distributing clearly responsibility for different parts of the recovery process
Re-enhance	Practices aimed at recovering from disruptions and exploiting opportunities that may arise from it	- Establishing a systematic process for handling supply disruption - Task forces employing a systematic recovery process for problem-solving - Offering enhanced value propositions to customers
Sustain	Practices aimed at sustaining operations and continuing to deliver value to customer.	- Managers actively involved and supporting the recovery process through allocation of resources - Cooperation - Developing long-term supplier relations - Adjusting production and delivery by balancing available resources

Source: adapted from Birkie (2016)

2.3 – Trade-offs between lean and resilient paradigms

As described in the first chapter, lean practices are focused on reducing wasteful activities, not only in manufacturing activities or within a single firm, but ideally in the entire value chain of a product or service. This transformation should translate into greater efficiency of the processes and a stronger flexibility of operations, allowing to reduce production costs and produce and deliver only the products and services that are needed, when they're needed (Ruiz-Benitez et al., 2019).

Instead, firms prepare for resilience by building practices that allow them to recover as rapidly and seamlessly as possible from unexpected disruptions. In literature therefore, the concept of resilience is often associated with the concept of redundancy (Nowell et al. 2017), which as mentioned can come in many forms, such as backup inventories of materials and products, or duplication of units and equipment: maintaining extra inventories and capacity as buffers is considered fundamental for obtaining reliable operations even in situations of crisis. Therefore, the two paradigms of practices seem to present a clear trade-off, because of their conflicting objectives (Ruiz-Benitez, 2019).

On the one hand, lean techniques, particularly when applied to production, are aimed at reducing and eliminating the redundancy of assets and processes within operations: according to lean management theory, redundant resources increase the complexity of operations, can hide the issues present within processes and supply chains, can lead to obsolescence of resources and products (Carvalho et al., 2011), and overall represent inefficiencies that add unnecessary costs to operations (Nowell et al. 2017). For all these reasons, lean paradigms prescribe a minimization of inventory levels. On the other hand, however, the same redundancies are considered to be among the main instruments available to firms to shield against uncertainty (Shefii and Rice, 2005): maintaining strategic inventories reduces a company’s vulnerability to unexpected events (Carvalho et al., 2011), since firms are able to rely on buffers of finished products or raw materials to recover rapidly in the case of unexpected disruptions, whether in the internal processes or in the supply chain. A similar reasoning can be made for the decision to keep extra capacity in the firm, or for duplication of efforts throughout the supply chain (Nowell et al. 2017).

These observations in literature, supported by news stories of operational failures which involved lean firms, have contributed to the idea that adopting lean may actually be damaging to firms operating in situations characterized by frequent disruptions. It’s argued that the efficiency obtained through the implementation of lean practices comes at the cost of a trade-off with the ability of coping with unplanned events: in fact, while the elimination of redundant capacity and supplier relationships are cost-efficient actions in the short term, they also make firm operations more vulnerable to unexpected shortages, disruptions or changes in the external environment (Christopher and Peck, 2004), leading to potentially negative financial implications (Chopra and Sodhi, 2014). These views appear to consider lean and resilience as incompatible paradigms: lean is considered a system which only works in a situation of stability, whose sustainability over time is threatened in environments characterized by unexpected variability (Ivanov et al., 2014).

However, it’s important not to forget that the topic is more complex than it appears, since lean practices can’t simply be reduced to inventory-reduction tools. Therefore, while it’s undeniable that trade-offs exists to a certain extent, it would be reductive to claim that the two paradigms are always in a trade-off. Moreover, both systems have been proven to bring individually positive effects on performance, and it would therefore seem ideal to have them both working together in a company (Maslaric et al., 2013). For the purpose of providing a full picture, now the arguments in literature supporting the presence of possible synergies will be addressed.

2.4 – Synergies between lean and resilient paradigms

Despite this apparent trade-off, recent works suggest the existence of a positive relationship between lean adoption and resilience. While strong empirical evidence is lacking, the existence of potential synergies between the two strategies is argued in the literature at conceptual level, particularly when lean management is applied extensively and including the supply chain.

For example, there are works focused on firm and supply chain sustainability that employ conceptual modeling approaches to study the combined impact of lean, resilient, agile and green practices (Azevedo et al., 2016; Carvalho et al., 2011; Ruiz-Benitez et al., 2017, 2018, 2019); thus, while not directly focused on studying the relationship between lean and resilience, they provide some useful insights on the potential synergies among the two paradigms. It is claimed that despite the above mentioned conflict regarding inventory management and redundancies, there are also overlapping practices to be found (Carvalho et al., 2011): for example, both lean and resilient paradigms commit to a reduction of lead times, both in production and transportation, which allows to develop a quicker response. Both paradigms also contribute to the involvement of supply chain partners in alliances or networks, which facilitates collaboration and information sharing: in fact, collaboration is considered to be an antecedent of resilience in supply chains (Scholten and Schilder, 2015), and improved communications can help lean organizations sustain a good performance even in dynamic environments (Azadegan et al., 2013). Another argument in favor of a positive relationship is that while lean practice sacrifice one of the two key resilience capabilities (Sheffi and Rice, 2005), redundancy in operations, they support the improvement of the other key resilience capability, flexibility in operations. Examples of the flexible capabilities that lean supports and that can lead to resilience include the creation of production systems that can be quickly adapted and converted for the production of different products, and the creation of a multi-skilled workforce (Carvalho et al., 2011).

An even more interesting observation is that the adoption of lean practices seems to act as a driver for the adoption of resilient practices (Ruiz-Benitez et al., 2017, 2018, 2019). A possible hypothesized explanation is that since lean firms are aware that they can't rely extensively on redundancies, and therefore have more vulnerable operations and supply chains, it becomes more pressing for them to develop resilient practices in order to minimize the negative consequences of a disruption caused by unexpected events (Ruiz-Benitez et al., 2017), making it more likely for them to implement resilient practices in addition to lean practices.

Other works provide further insights in support of the synergistic relationship. Lotfi and Saghiri (2018), while studying the separate impacts of lean, agile and resilient practices on organizational performance outcomes, find that a higher level of leanness may lead to a better recovery time, and consequently to a higher resilience in the system. In addition, resilient practices, implemented in parallel with lean practices, are found to improve operational performance in terms of cost, delivery and flexibility. A different perspective (De Sanctis et al., 2018) focuses on the impact of human factors on organizational resilience, suggesting that a stronger learning capacity - improved in lean organizations because of cross-training, job rotation, participation to decision making - will positively impact resilience.

While investigating the resilience in Swedish SMEs during economic recessions, Pal et al. (2014) hypothesize a series of factors and capabilities that can lead to stronger operational resilience, and among these factors they include the implementation of effective lean management. They argue that lean management can increase firms' operational flexibility, for example through the development of standardized processes, shorter lead times, rapid response to demand, seamless integration of processes and concurrent engineering techniques.

Birkie (2016) is the first author to investigate empirically the synergy and trade off relationship between resilience and lean at company level, finding that the synergies appear to outweigh the trade-offs. In his work, five core functions of operational resilience are considered - sense, build, reconfigure, re-enhance, sustain (see Table 2.1) - and these bundles of practices are then compared with established bundles of lean practices, such as company-focused bundles like Just-in-Time, Total Quality Management, Total Productive Maintenance, Human Resource Management, but also bundles connected to external factors, such as the collaboration with suppliers, lean purchasing and the active involvement of customers. What emerges from the analysis is that an aggregate level positive synergies exist between the bundles of lean practices and the core operational resilience practices, implying that their combined effect is stronger than their individual contribution to performance. However, when testing for the effect of individual bundles of lean practices, production-focused bundles such as TPM and JIT seem to be instead in trade-off with resilient practices. Then again, it could be argued that this is in line with previous findings in lean literature, claiming that the positive impact of lean practices on performance is greater when it's not limited to a few practices and several bundles of practices are instead implemented simultaneously (Shah & Ward, 2003).

2.4.1 - Lean and *supply chain* resilience

While this work is focused on resilience at firm level, it's worth to briefly mention some literature contributions on *supply chain resilience*, since many works addressing the relationship between lean and resilience focus on this wider concept. As a reminder, the concept of *supply chain* indicates the set of organizations that interact with one another in order to create a product or service, from the raw materials to the delivery to the final customer, and thus *supply chain resilience* can be defined as the "adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations" (Ponomarov and Holcomb, 2009, p.131).

The debate on the relation among lean and resilience presents arguments similar to those previously presented in relation to single organizations. In support of the trade-off argument, it's been argued that the pursuit of efficiency and cost reductions, pursued through the application of lean in the years before the 2007 crisis, had left supply chains lacking resilience, too vulnerable to cope with the increasingly volatile demand and supply (Purvis et al., 2016). Moreover, authors who conducted research on supply chains in the automotive industry (Govindan et al., 2015) also claimed that the adoption of lean practices can lead to more vulnerable supply chain, and that specifically JIT practices can provoke operational failures if there are disturbances in the regular flow of materials.

Considerations in favor of a synergistic relationship suggest again that the two paradigms present overlapping practices, specifically regarding the approach to communication and information sharing between the company and its suppliers (Ruiz-Benitez et al., 2017, 2019). Authors Cabral et al. (2012) consider both lean and resilience among the paradigms necessary to build a competitive supply chain, although they recognize that the existence of trade-offs among the two requires a careful selection of which practices to implement. Purvis et al. (2016), through a case study, propose a framework for the development of a resilient supply chain strategy, and identify the importance of the lean paradigm - among others - to increase a company's ability to manage disruptions. Table 2.2 below provides a summary of the main contribution on the relationship among lean and resilience, including both works focused on firms and on supply chains.

Table 2.2 - Summary of literature contributions regarding the relation among lean management and resilience.

Authors	Approach	Focus	Contributions
Azevedo et al., 2016	Model illustrated through a case study	Supply chain resilience	The work supports the existence of trade-offs and synergies among lean and resilient paradigms. An example of a trade-off is the different approach to strategic inventory.
Birkie, 2016	Empirical study	Organizational resilience	At an aggregate level, lean and resilience are found to show positive synergies. However, if JIT and TPM lean bundles are considered individually they show a trade-off relation with resilience.
Carvalho et al., 2011	Conceptual model	Supply chain resilience	Synergies between lean and resilient paradigms are identified, including the reduction of production and transportation lead time, and the increased level of integration and information sharing with suppliers. Divergencies are also identified, relatively to the different approaches to inventory levels and capacity surplus.
De Sanctis et al., 2018	Conceptual model	Organizational resilience	Considers the impact of the workforce's learning capacity and attitudes on resilience in lean organizations, through the development of a model.
Govindan et al., 2015	Conceptual model	Supply chain resilience	In the automotive industry, JIT practices are found to be in trade-off with resilient practices, since they could generate production failures upon disruptions
Lotfi and Saghiri, 2018	Model tested on empirical data	Organizational resilience	Finds that in the automotive industry both lean and resilience have positive impact on operational performance. Moreover, a higher level of leanness appears to help reduce the time necessary for recovery.
Pal et al., 2014	Empirical study	Organizational resilience	In SMEs, the effective implementation of lean management is considered to be among the antecedents of organizational resilience, because of its contribution to operational flexibility and to organizational robustness.
Purvis et al., 2016	Case study	Supply chain resilience	Finds that lean practices must be included, among other paradigms, in the development of a resilient supply chain strategy.
Ruiz-Benitez et al., 2017, 2018, 2019	Conceptual model	Supply chain resilience	The works support the existence of both synergies and trade-offs among lean and resilient practices, and find that lean practices appear to act as drivers for resilient practices, specifically in the aerospace sector.

Source: personal elaboration

2.5 - Measuring organizational and economic resilience

Before moving on to any analysis, there is an additional aspect to consider. Independently from the matter of any possible relationship with lean management, what emerges from the literature review is that the concept of resilience itself has been highly debated, with contrasting opinions about its definition and about the factors and practices that can enhance it. Another issue that appears is the matter of how resilience can be concretely measured, and more importantly whether it can be measured through economic and financial indicators. The limited empirical investigation on the topic is considered to be a consequence of the difficulty in collecting data that can clearly reflect the resilience of a firm, since it's a complex concept, that cannot be observed directly and that involves cultural factors (Desjardine et al. 2019), and as such it's difficult to measure through economic and financial indicators.

While therefore there isn't a universal agreement on an indicator able to measure resilience, it's worth to mention examples of the possible approaches that were employed in previous literature. Some researchers have focused on measuring the resilience of firms as a generally superior level of performance: an example of a similar approach is found in Santoro et al., (2020), who interpreted economic resilience as a relatively superior performance of a firm against the performance of its competitors, self-evaluated by the firms in terms of their relative profits and relative growth. A different approach was adopted by Markman and Venzin (2014), while investigating the resilience of firms in the financial services industry: they interpreted economic resilience as a persistently superior performance, measured through an indicator based on firms' ROE and on the volatility of their stock prices.

Other authors have attempted to measure resilience by considering the performance of firms in reaction to concrete disruptions. Ambulkar et al. (2015) asked a sample of firms who had faced a disruption in their supply chain to measure their resilience by self-evaluating their abilities to cope with changes, to provide a quick response, and to maintain a high situational awareness. Desjardine et al. (2019) instead adopted an approach based on stock prices: researching organizational resilience following the 2008 crisis, they measured economic resilience of U.S. firms in two ways: through the severity of loss and through the time to recovery, both of which were calculated by considering the variations of stock-prices. De Carvalho et al. (2016) instead, while studying whether innovation positively impacts organizational resilience, considered resilience as a superior financial performance in the years following the 2008-2009 crisis, measured through EBITDA, ROE and ROA indicators.

As for the previously mentioned works that considered to some extent the relationship among lean management and resilience, Birkie (2016) evaluated the resilience of firms following a disruption in terms of operational performance, evaluating the relative variations of five operational performance metrics (quality, cost, speed, flexibility, dependability) in the quarters after the disruption occurred. Instead Pal et al. (2014), investigating the antecedents of resilience to the 2008 crisis in the Swedish textile industry, considered economic resilience by employing Altman's Z-Score, an indicator generally employed to predict bankruptcy potential, built through information that represent the company's profitability, solvency, liquidity and leverage.

To conclude, what appears clear is that there are still many limitations in the literature addressed, first of all the fact that very few works address the relationship through an empirical approach, given also the difficulty in measuring resilience. However, understanding better the nature and the extent of the relationship could prove quite useful for decision-making: since being resilient is increasingly important, and both building resilient capabilities and implementing lean practices require investments in resources and projects, the existence of a positive relationship would be an incentive in favor of a simultaneous implementation of the two paradigms. Therefore, while the topic still appears controversial and unexplored, further research is not only possible, but appears to be necessary.

CHAPTER 3

SAMPLE DESCRIPTION

Among the many lean works conducted throughout the years many have focused on analyzing the different lean practices - either individually or in bundles – and the impact of these practices on economic and financial performance. However as stated in the previous chapter there is still a lack of works investigating how the performance of lean firms is affected in periods of crisis. The purpose of this work is therefore to investigate the relationship between lean adoption and performance in situations of increasing turbulence, with the aim of understanding whether the implementation of lean practices can significantly reduce of enhance the resilience of firms. In order to attempt this, an analysis will be conducted, employing data from a sample representative of the Italian manufacturing industry.

3.1. - Data gathering

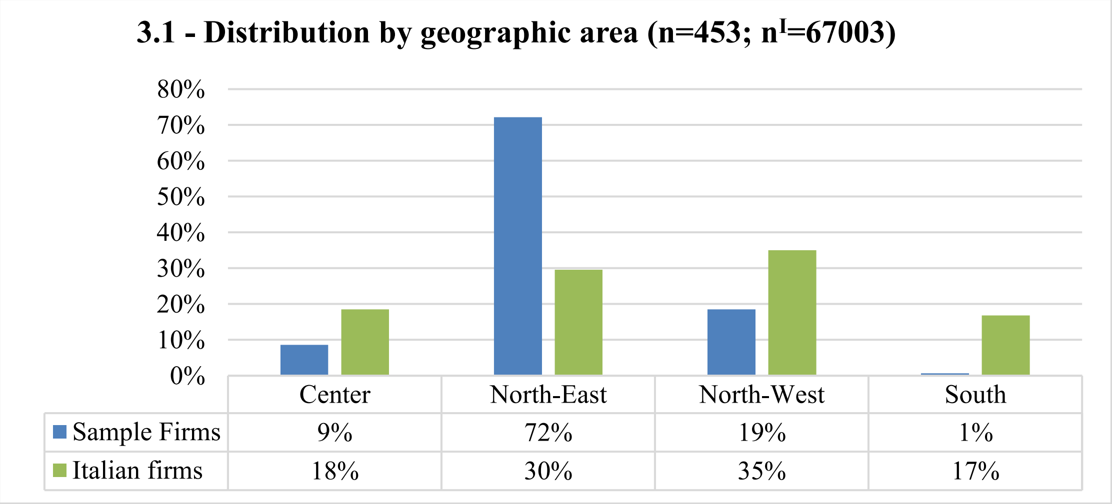
The analysis started from a database comprising data from 454 Italian manufacturing firms. The information in the database was gathered throughout the years 2009-2019 and derived from two different sources. The primary source was a survey designed by the Department of Economics and Management "Marco Fanno" of the University of Padua, which was submitted via e-mail to a sample of Italian manufacturing companies, identified through the ATECO two-digit code between 10-32[1]. The answers collected provided information about demographic and internal features of the firms involved (such as their geographic location, the number of employees, the main markets in which they operate, to cite a few) and also information regarding their implementation and different approaches to lean practices. In addition, the data collected from the firms who answered the survey was then integrated with information from a second source, the AIDA database. Specifically, financial information were added for each firm up to the year 2018, including but not limited to revenues, indicators of profitability (such as return on equity, return on assets, return on investment, return on sales), and indicators of leverage such as debt-to-equity ratio.

---

[1] The ATECO 2007 classification has been employed in Italy since the year 2008, to classify businesses in different industries according to their main activities, using a code of six digits (Source: ISTAT)

Some preliminary observations should be made to assess the validity of the sample in representing the Italian manufacturing industry. To perform a comparison between the sample gathered through the survey and the entire Italian manufacturing industries, additional data was gathered from the AIDA database, selecting a sample of Italian firms based on two criteria: manufacturing firms belonging to the ATECO two-digit interval 10-32, such as those present in the sample; and active firms, to exclude those in liquidation. What emerged was a sample of 67003 firms, that was compared with the sample of 454 firms to evaluate aspects three main aspects: industry distribution, geographic distribution and firm dimensions.

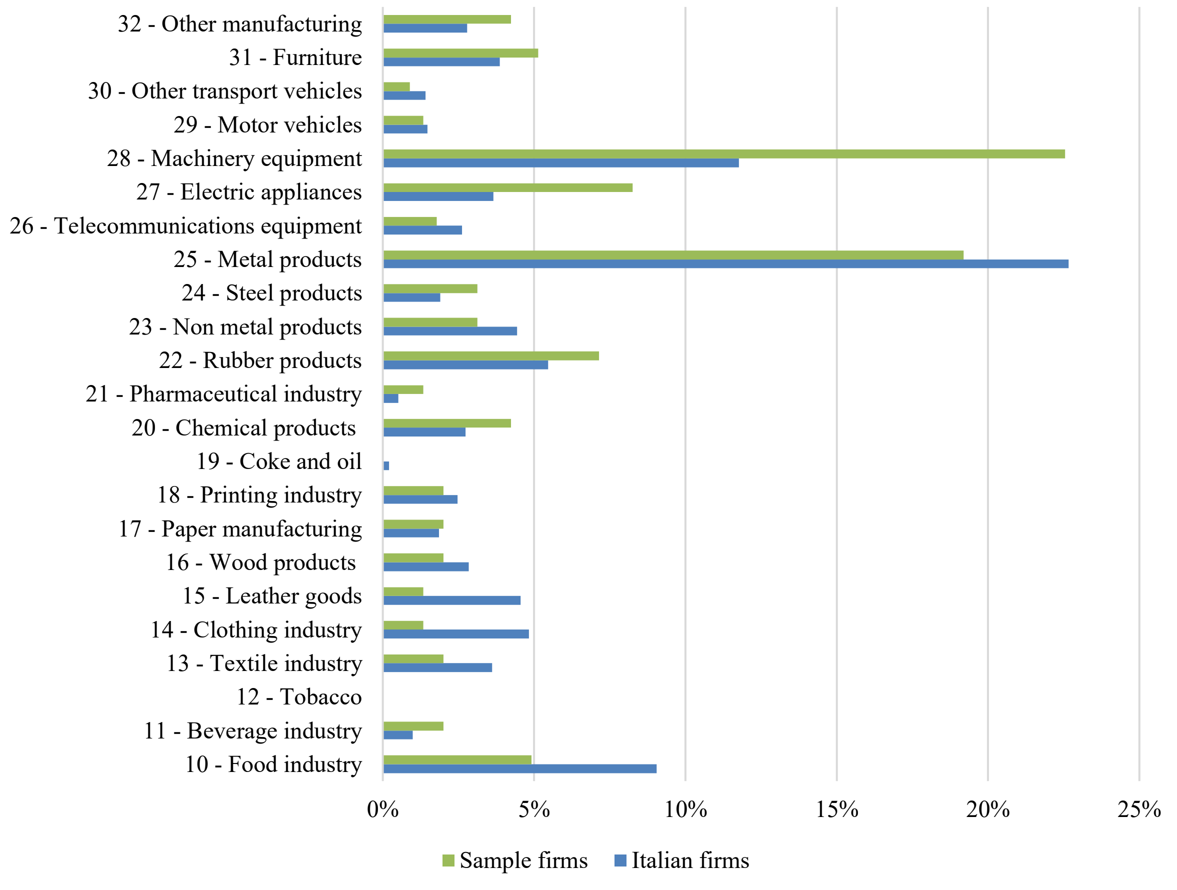
To evaluate the geographic distribution of the firms, the Italian market was divided in four areas: North-West (firms from Liguria, Lombardia, Piemonte and Valle d'Aosta), North-East (firms from Emilia-Romagna, Friuli-Venezia Giulia, Trentino Alto Adige and Veneto), Center (firms from Lazio, Marche, Toscana and Umbria), and South (firms from Abruzzo, Basilicata, Campania, Molise, Puglia, Sardegna, Sicilia). It appears that most firms in the collected sample are located in the North-East and North-West, while the Center and South are less represented (Graph 3.1). However the comparison with the distribution of Italian manufacturing firms confirms a stronger concentration of manufacturing firms in the Northern areas of Italy, so the sample could still be considered valid, although more focused on the North.


3.1 - Distribution by geographic area (n=453; n^{I}=67003)

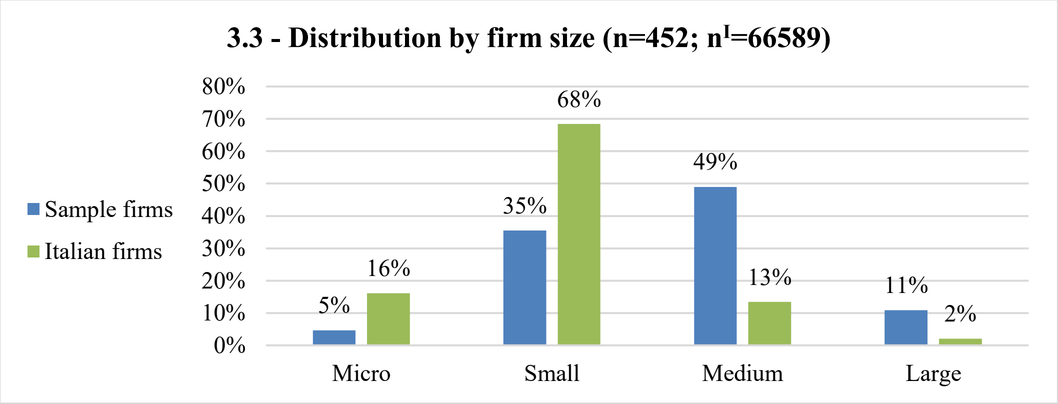
	Center	North-East	North-West	South
🟦 Sample Firms	9%	72%	19%	1%
🟩 Italian firms	18%	30%	35%	17%

A second observation shows the different sectors represented in the sample. As mentioned before, all the firms were pre-selected to be manufacturing firms, and therefore have a two-digit ATECO code comprised between 10 and 32, which identifies the macro area of their activity. The further analysis of these two-digit ATECO codes (Graph 3.2) shows that the firms in the sample are representative of 21 industries, with no data relative to ATECO 12 (Tobacco industry) or ATECO 19 (Manufacture of products deriving from the refining of petroleum). However this result is not surprising, since the comparison with the Italian sample shows that those sectors also constitute a minority of Italian firms. Most firms in the sample are concentrated in the following industries: manufacture of machineries (ATECO 28), manufacture of metal products (ATECO 24 and 25), manufacture of electrical equipment (ATECO 27) and chemical industry (ATECO 20 and 22). While the sample is under representative of certain industries, such as clothing and textile (ATECO 13 and 14) or food (ATECO 10), and over representative of the machinery industry (ATECO 28), the comparison with the Italian firms (Graph 3.2) confirms a similar distribution among most of the 21 industries, suggesting the validity of the sample in terms of industry distribution.

3.2 - Distribution by ATECO 10-33 (n=448; n^{I}=67003)

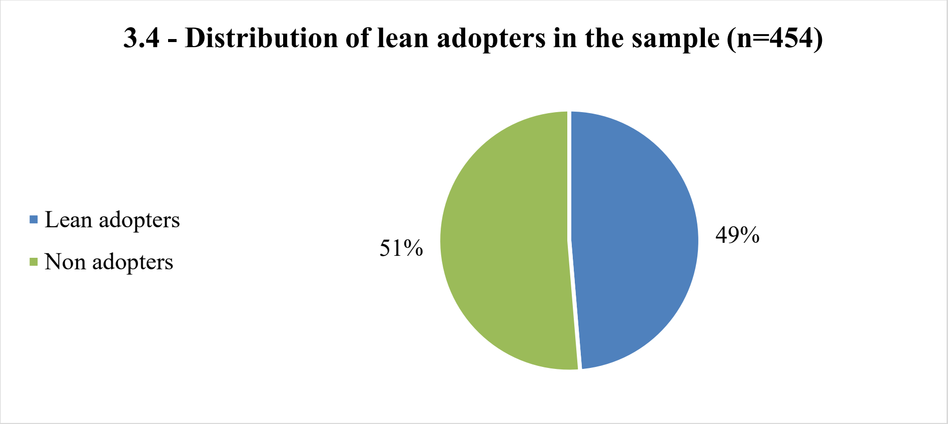


A third analysis can be made comparing the dimension of firms, evaluated based on the number of employees of each firm. Firms were divided in four categories: micro (less than 10 employees), small (10 to 49 employees), medium (50 to 249 employees) and large (more than 250 employees). The sample appears over representative of medium and large firms and under representative of small and micro firms (Graph 3.3). However, the most represented categories are indeed small and medium firms, which constitute 84% of the sample, which also represent the core of the Italian manufacturing industry, representing the 81% of the Italian manufacturing firms, so it can be considered valid.



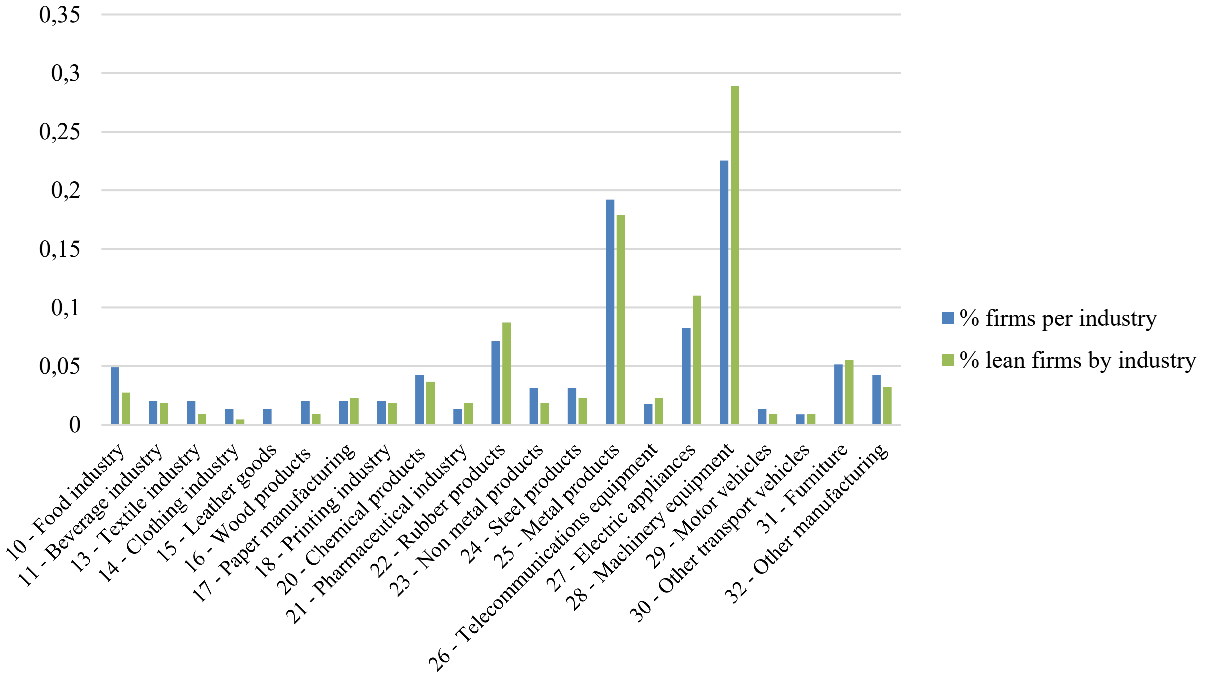
These first observations regarding the demographic characteristics of the firms in the sample allow to state that this sample can be considered a good proxy of the Italian manufacturing industry, although biased towards the Northern regions and towards specific industries.

The survey provides further information about the answering firms, which will be described further in the chapter. One of the main insights provided for the purpose of our analysis is the amount of lean adopters in the sample (Graph 3.4): firms who self-identified as lean adopters, because they claimed to adopt at least one lean practice, were 221, or 49% of the sample.

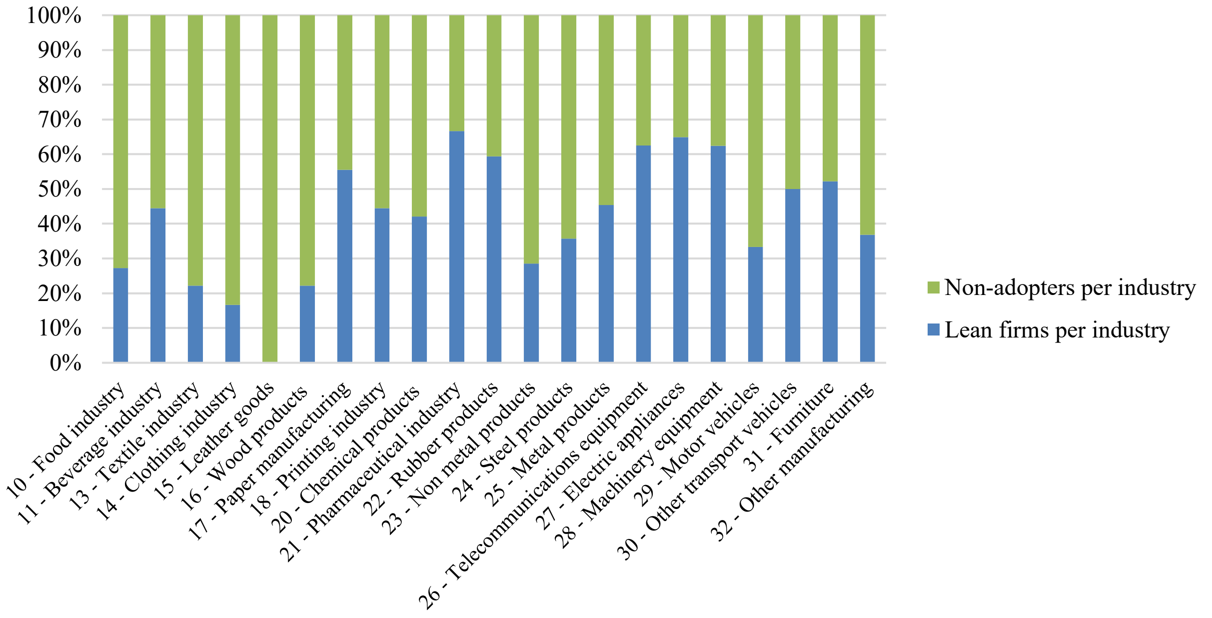


As will be described in the next paragraph, the further analysis will focus on a reduced number of sectors, so it’s interesting to evaluate to which ATECO two-digit industries the lean firms of the sample belong to, to see if there is a significant difference in lean adoption depending on the industry. The graph below (Graph 3.5) shows that the distribution of lean firms across industries is quite similar to the general industry distribution that was found in Graph 3.2. However, looking at the percentage of adopters and non-adopters in each industry (Graph 3.6) it seems that lean is more diffused in certain industries, particularly in more innovative and technology-intensive industries such as the pharmaceutical industry, the electric appliances production and the machinery industry, while it’s less common in more traditional industries such as the food industry, the textile industry, leather production or wood manufacturing.

3.5 - Lean firms by industry (n=448; n^L=218)



3.6 - % Lean adopters and non adopters per industry (n=448)



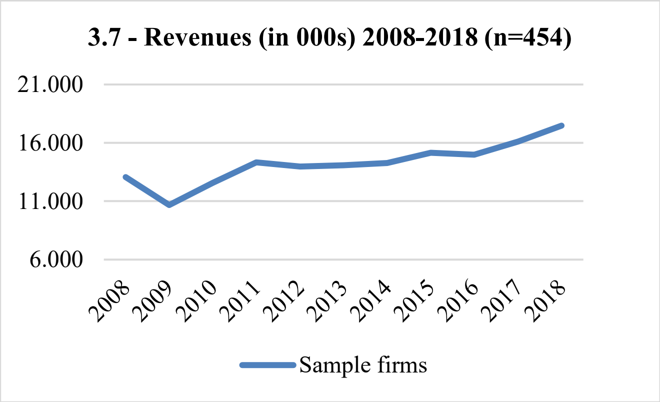
3.2 - Identification of periods of crisis: sample adjustment

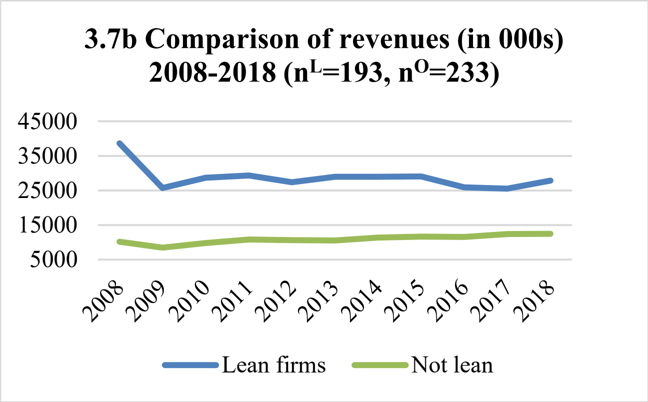
The aim of this work is to investigate whether the adoption of lean management can improve or reduce the resilience of a firm in periods characterized by crisis or by unexpected turbulence in their business activities. Specifically, this analysis will measure the resilience of a firm in terms of a superior financial performance during periods of activity characterized by a high variability, to evaluate whether the adoption of lean represents an element of distinction. Having thus established the validity of the sample in representing the Italian manufacturing industries, a necessary step at this point is therefore to identify situations of disruption or crisis that may have affected the performance of firms in the sample.

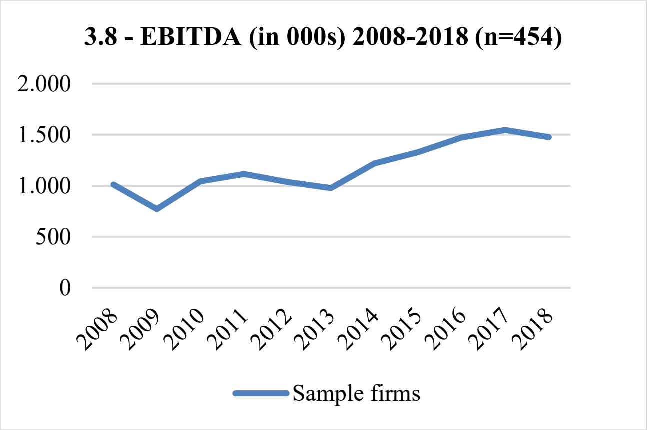
A possible approach could be to consider internal or individual disruptions, such as the failures that may occur along firms' supply chains or the unexpected technical issues that may be generated by breakdowns of machineries; however, the data gathered through the survey doesn't provide any information regarding previous disruptions, and given the prevalence of SMEs (82% - Graph 3.14) and family businesses (70% - Graph 3.15) in the sample it isn't possible to retrieve this kind of information from public secondary sources (method adopted in Birkie, 2016). An alternative approach could be to consider the performance during or following periods of turbulence, such as those that may be caused by large-scale disruptive events like an economic crisis (similar to the approaches adopted in Pal et al.,2014 and in Carvalho et al.,2016). A significant example of a large-scale disruptive event is the economic crisis of 2020, caused by the diffusion of Covid-19 and by the consequent actions undertaken to contain the pandemic, a crisis which is ongoing at the time of writing and for which it's still too early to evaluate the response of firms in terms of resilience.

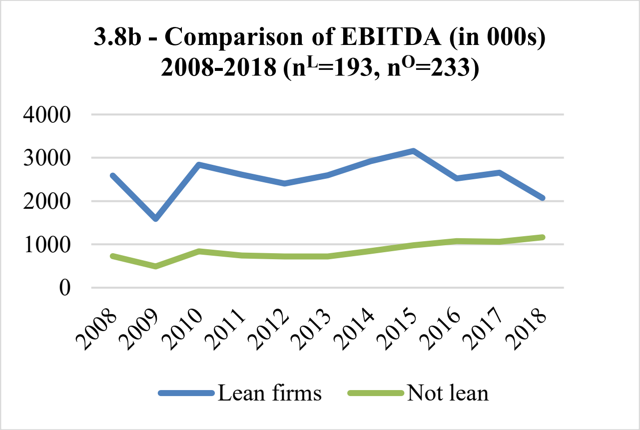
However, there is reason to believe that periods of turbulence may be identified in the ten-year period covered by the data available. In fact, during the 2008-2018 another significantly disruptive event occurred, the 2008 global crisis, which until 2020 had represented the most significant economic crisis since the aftermath of WW2, and that had repercussions on the global economy for several of the subsequent years. As a first step, it can be therefore useful to verify whether the firms in the sample were affected by periods of turbulence, which can be attempted by looking at the graphical trends of the financial indicators available over the 2008-2018 period, obtained from the AIDA database. The first graph (Graph 3.7) shows the revenues over the period, computed as the sample's median values for each year; it appears clear that the first years were characterized by turbulence in the results, and in particular in

2009 a significant drop in revenues occurred. The following graph (Graph 3.8), focused instead on EBITDA[2], shows a similar trend, with an apparent additional decline in 2013.


3.7 - Revenues (in 000s) 2008-2018 (n=454)


3.7b Comparison of revenues (in 000s) 2008-2018 (n^L=193, n^O=233)


3.8 - EBITDA (in 000s) 2008-2018 (n=454)

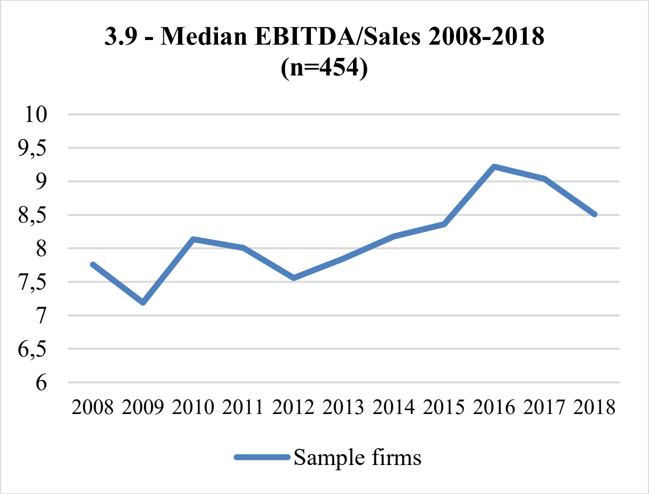

3.8b - Comparison of EBITDA (in 000s) 2008-2018 (n^L=193, n^O=233)

To search for further confirmation, other financial indicators are investigated. Graph 3.9 shows the trend for EBITDA/Sales, a common indicator of firms' profitability. For this indicator, the graphical results show again some instances of turbulence, with a negative downturn in 2009 and 2013. The subsequent graphs (Graphs 3.10-3.13) are focused instead on ROE, ROA, ROI and ROS[3], other common indicators of firm performance. Once again, the trend shows a significant decline in 2009, and a second negative peak between the years 2012-2013. It's important to remember that the sample includes firms of different sizes and industries, and thus these graphs represent a simplification of the complex economic situation in the Italian manufacturing industries over the period considered; however these observations allow us to understand that on average the firms in the sample didn't operate in a situation of stability over the entire ten-year period, and particularly appear to have been negatively affected as a consequence of the 2008 global crisis.

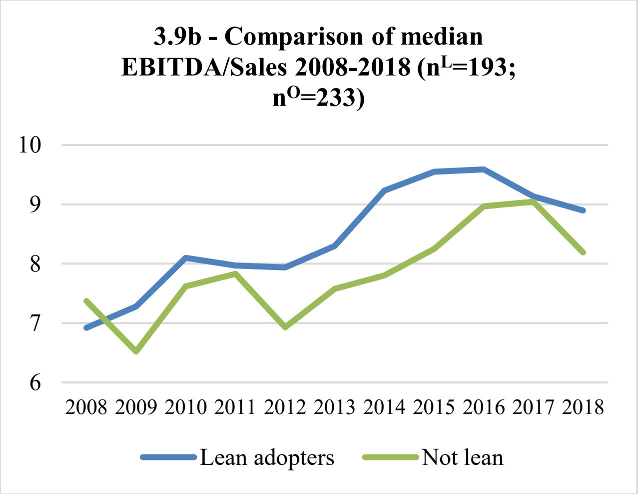
---

[2] EBITDA indicates Earnings Before Interests, Taxes, Depreciation and Amortization. It's employed to evaluate the operating performance of company, showing the financial performance independently from the company's capital structure.

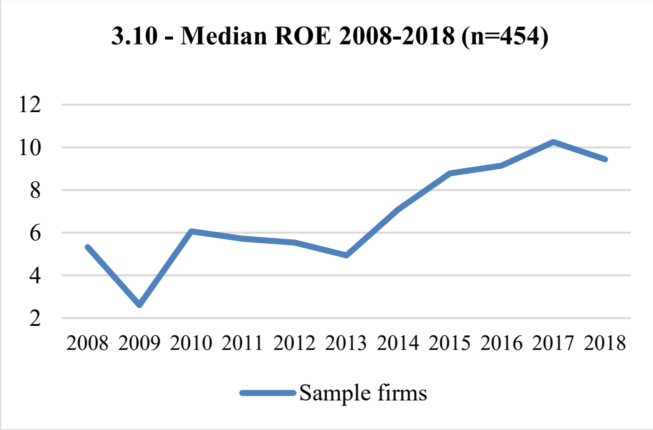
[3] ROE = net income / shareholders' equity
ROA= EBIT / total assets
ROI = EBIT / operating net invested capital
ROS = EBIT / sales.



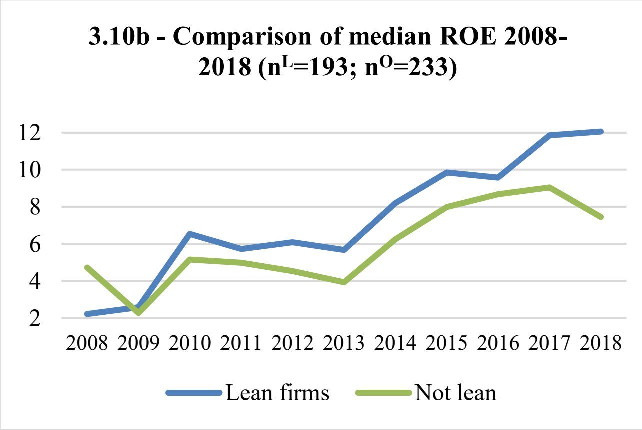
3.9 - Median EBITDA/Sales 2008-2018 (n=454)



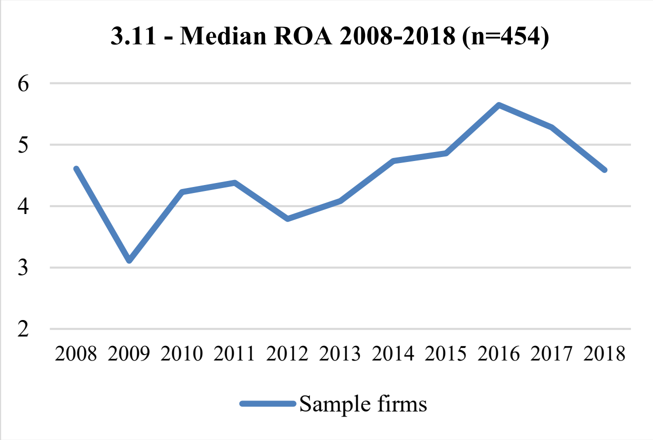
3.9b - Comparison of median EBITDA/Sales 2008-2018 (n^L=193; n^O=233)



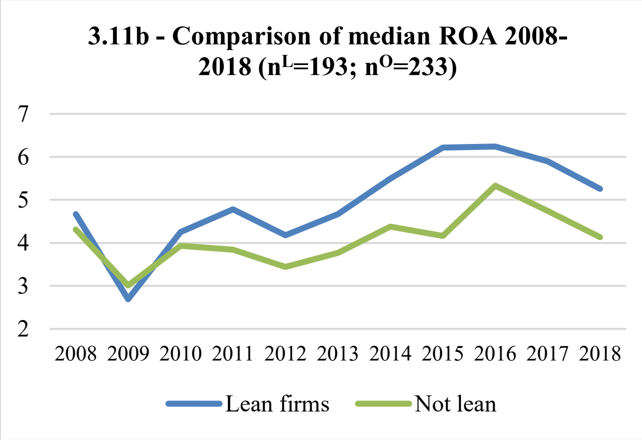
3.10 - Median ROE 2008-2018 (n=454)



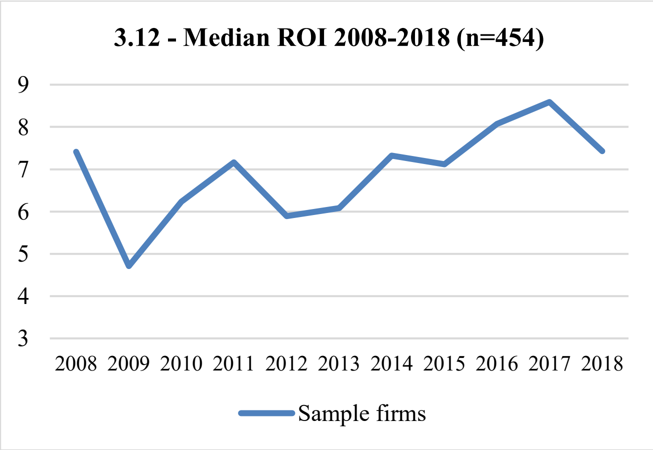
3.10b - Comparison of median ROE 2008-2018 (n^L=193; n^O=233)



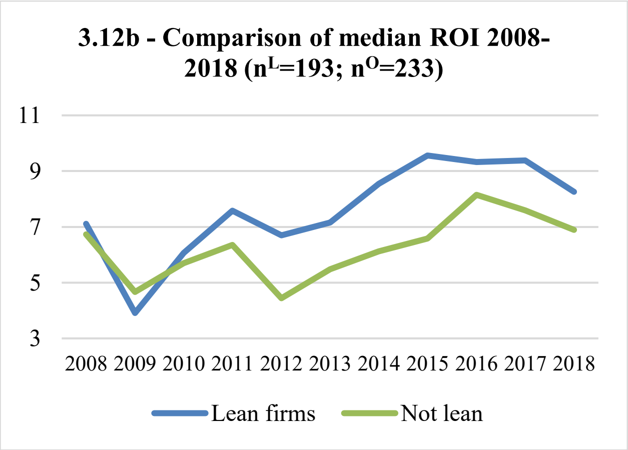
3.11 - Median ROA 2008-2018 (n=454)



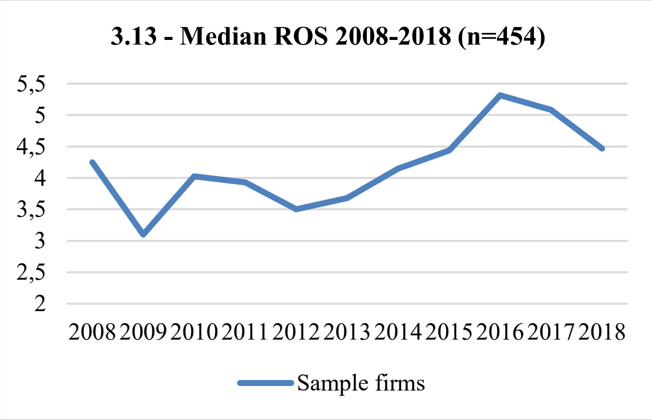
3.11b - Comparison of median ROA 2008-2018 (n^L=193; n^O=233)

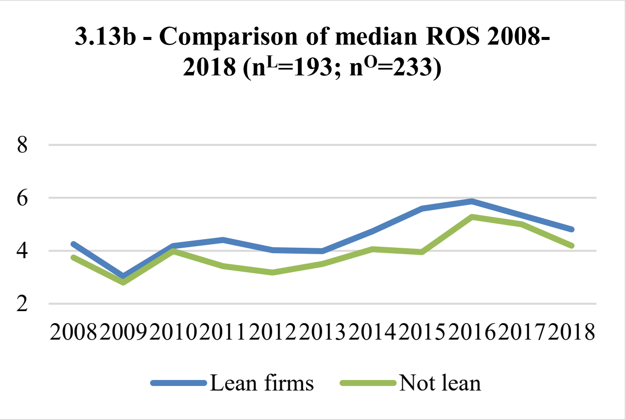


3.12 - Median ROI 2008-2018 (n=454)



3.12b - Comparison of median ROI 2008-2018 (n^L=193; n^O=233)





Beyond these observations, the graphs on the right side (from 3.9b to 3.13b) show the same indicators, but providing a comparison among lean adopters and non-adopters in the sample, over the same period of time. For the purpose of these graphs, and to avoid misleading results, financial data regarding lean adopters were only included for the years following their lean implementation. While again these graphs are a simplified representation of the complex reality of the Italian manufacturing industry, it appears that lean adopters have shown through the years a consistently superior performance compared with non-adopters. However, focusing on the performance in the most turbulent years, and particularly in 2009, it appears that lean firms were also severely impacted by the crisis, and for certain indicators (such as ROA and ROI) the graphs show even worse values of their means when compared with their not-lean counterparts.

Reports from ISTAT[4] investigating the state of the entire Italian manufacturing industry in the years following the financial crisis support the hypothesis of a particularly turbulent period in the first half of the decade, registering a first period of crisis in 2009, followed by a brief recovery window in the years 2010-2011, and then by a second crisis that started in the second half of 2011 and lasted, depending on the industry, up to 2013-2014, caused mainly by a contraction in the internal demand. However, these reports also offer another relevant observation: while none of the industries was exempted from the crisis, some industries were affected more severely than others. Considering this information, it's therefore worth at this point to shift the focus at industry level, to try and understand whether some of the industries represented in the sample were affected more severely by periods of crisis, either related to the 2008 crisis or independent from that specific event.

---

[4] ISTAT is the Italian National Institute of Statistics, the main publisher of official statistics in Italy. Starting from 2013, it has produced every year a report investigating the competitiveness of the Italian manufacturing and service industries. (Source: ISTAT)

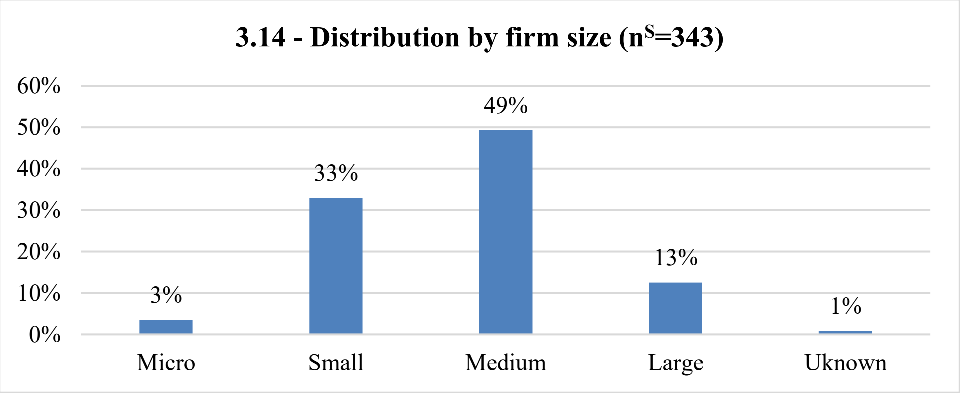
To proceed with the analysis, some adjustments to the database are thus necessary. As previously shown (Graph 3.2) the sample constitutes a good proxy of the Italian manufacturing industry, as the distribution of firms along the ATECO-two digits in the sample follows closely the distribution of the entire Italian manufacturing industry. However, given that 21 industries are represented in a sample of 454 firms, the number of firm observations in certain industry sub-samples is extremely low (the full breakdown of industry membership is shown in Appendix 1), and it must be considered that analysis derived from samples of such limited dimension wouldn't provide particularly meaningful insights. Therefore as a preliminary step some of the two-digit industries performing related activities were merged, and the remaining sectors for which less than 20 observations were available were excluded; the result were the six industry sub-samples listed in Table 3.1, on which the remaining analysis will focus.

Table 3.1 – Selection of six industry sub-samples

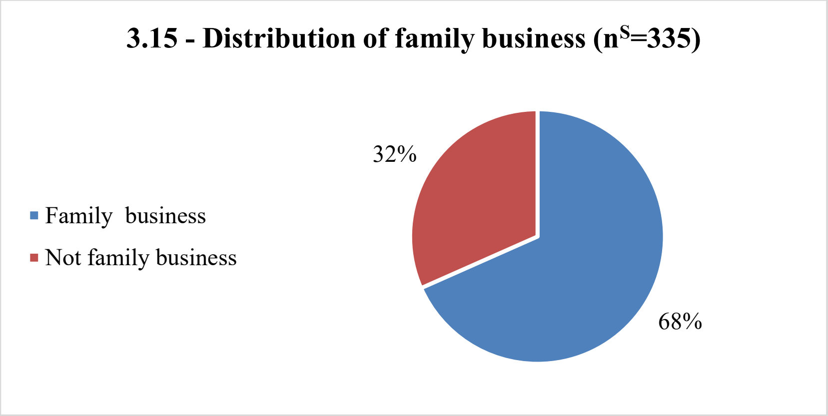
Industry	***Sample firms per industry***	***Lean firms per industry* (as of 2019)**	***Lean firms per industry* (as of 2009)**
ATECO 10-11: Food and Beverage	31	10	3
ATECO 20-22: Chemical	51	27	10
ATECO 24-25: Metals industry	100	44	16
ATECO 27: Electrical	37	24	10
ATECO 28: Machinery	101	63	21
ATECO 31: Furniture	23	12	3

3.3 - Main features of the sample

At this point, some additional considerations can be made to observe other possibly significant features of the firms in the sample selected, based on the data derived from both the survey results and the AIDA database. Graph 3.14 shows the distribution of firm size, which shows again a prevalence of small (33%) and medium firms (49%) in the sample selected.



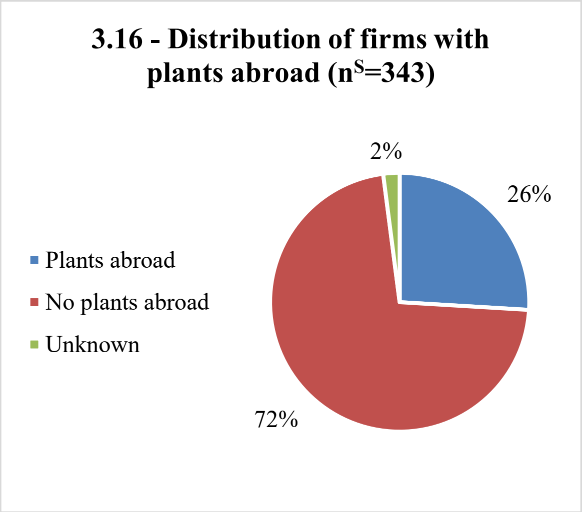
The data derived from the survey allows to evaluate some further organizational features of these firms. In terms of governance, Graph 3.15 shows that 68% of firms in the sample are family businesses, against 32% of non-family businesses: this is in line with the general trend in Italy, as family-controlled firms are estimated to comprise the 65% of large firms and up to 85% of small firms[5].

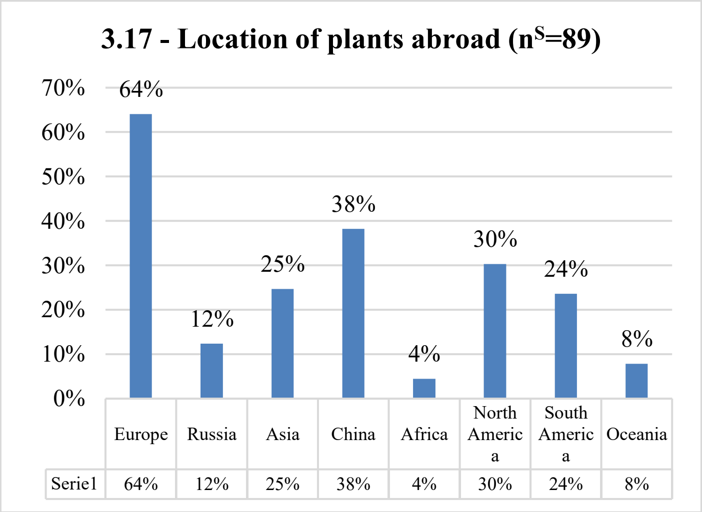


Given this majority of family businesses, it can be interesting to analyze the approaches adopted by firms towards internationalization, both in terms of production and export. The majority of firms in the sample (72%) indeed has only manufacturing plants located in Italy (Graph 3.16), and among the 26% of firms that instead have at least one production facility located abroad (Graph 3.17), most plants are located in other European countries (64%), followed by Asian countries, with China in particular (respectively 25% and 38% in China specifically) and North and South America (respectively 30% and 24%).

---

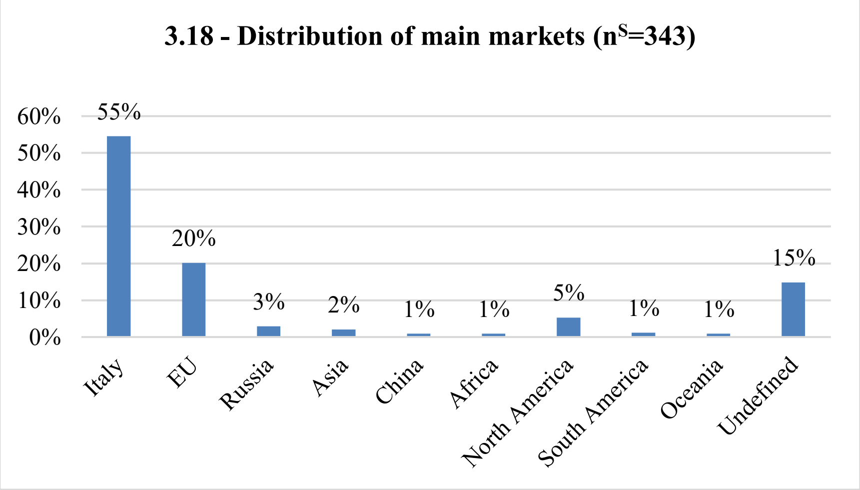
[5] Source: Associazione italiana delle aziende familiari





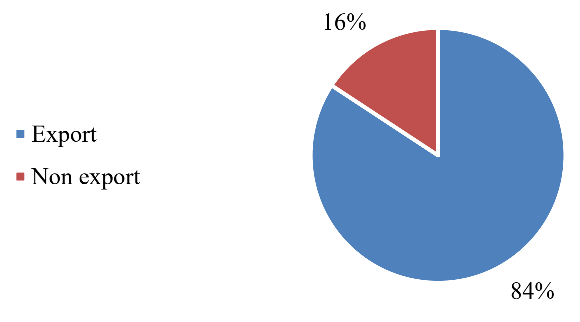
	Europe	Russia	Asia	China	Africa	North America	South America	Oceania
Serie1	64%	12%	25%	38%	4%	30%	24%	8%

The evidence that the majority of the firms in the sample have plants located exclusively in Italy is in line with another information that emerges, which is the fact that 55% of firms in the sample consider Italy to be their main market (Graph 3.18). However there is also a 20% of firms that consider other European countries to be the their main markets, which could be related to the decisions of building manufacturing facilities in Europe. Extra-EU countries are considered a main market only by around 14% of the firms in the sample, with North America representing the most important among the extra-EU (5%), while China and other Asian countries only represent a main market for 3% of firms, despite being the location of 63% of foreign plants.



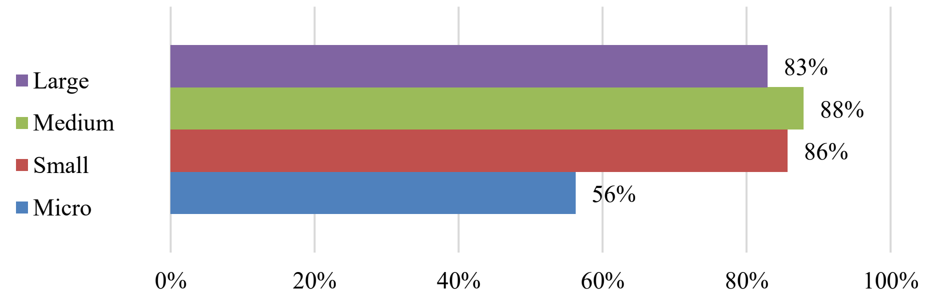
This last observation suggests that the markets in which the firms in the sample interact are not necessarily the markets where their plants are located. For this purpose, a further exploration can be made by looking at the firms' export behavior. While most firms have their facilities in Italy and consider it to be their main market, 84% of firms in the sample affirm to export, while only 16% of firms are focused strictly on the internal Italian market (Graph 3.19).

3.19 - Distribution of export firms (n^S=343)

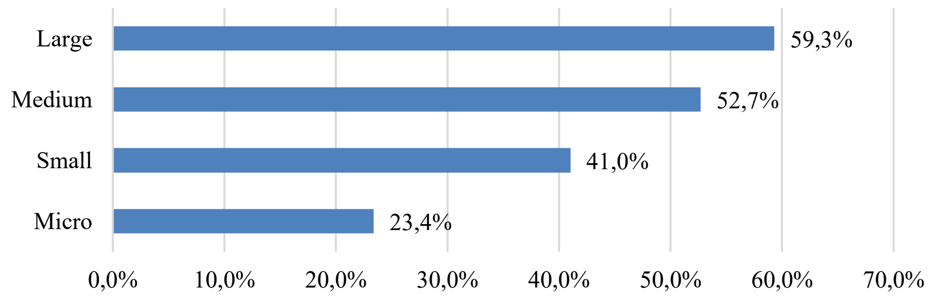


In situations of demand crisis in the internal market, export can become a vital opportunity for firms to maintain resilience, and so it's worth to observe the attitude towards exporting more specifically. Observing the percentage of exporters in each class of firms' dimension, what emerges is that small and medium sized firms are more inclined to export, with respectively 86% and 88% of firms being exporters, above the average (Graph 3.20). Large firms are also significant exporters, while the exception is represented by micro enterprises, which are below average with only 56% of exporters. In terms of the average turnover realized through exporting, it appears to have a more significant weight in medium and large firms (respectively 52,7% and 59,3% of the overall turnover), while it has a less significant weight in small and micro enterprises (respectively 41% and 23,4%), suggesting that firms of these dimensions might focus more on the internal market (Graph 3.21).

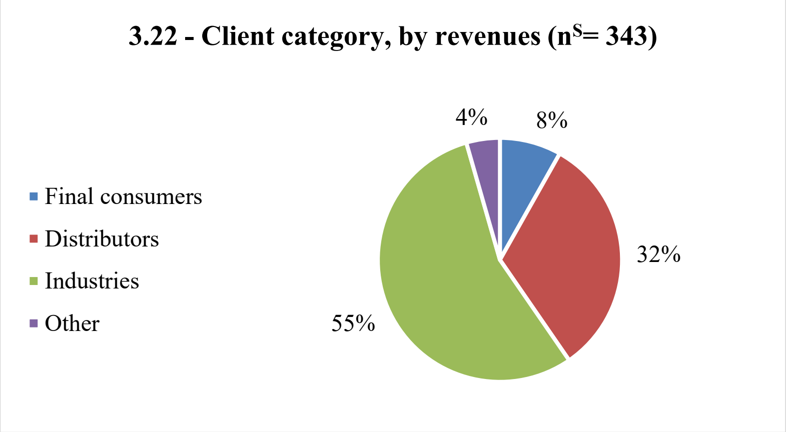
3.20 - Exporters by firm size (n^S=343)



3.21 - Average foreign turnover by firm size (n^S=343)

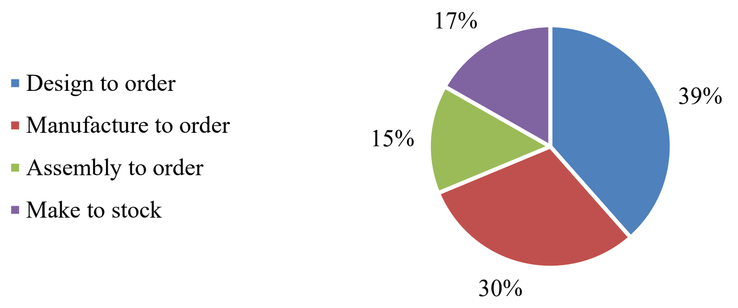


Beyond these observation regarding the attitude towards foreign markets, the information gathered also provides insights on other internal features of the firms in the sample. The revenues can in fact be considered not only in terms of internal market and export, but also in terms of client category. What emerges is that the majority of revenues for the firms in the sample is generated through sales to industrial partners (Graph 3.22): B2B sales represent 55% of revenues, and sales to distributors represent 32%, while direct sales to customers only account for 8%.

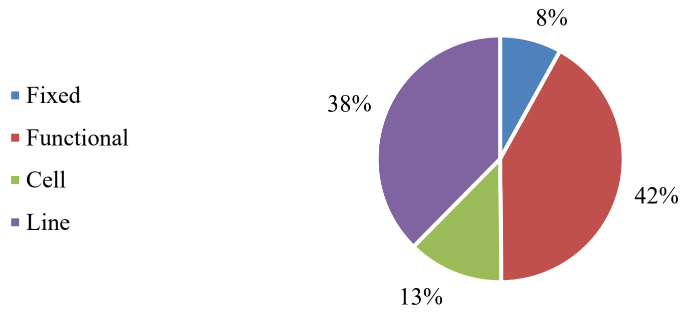


The survey also investigates aspects related to production. Looking at the production methods adopted (Graph 3.23), what emerges is that the most common methods are design to order and manufacture to order (respectively 39% and 30%), followed by make to stock (17%) and assembly to order (15%). Design to order is a method according to which the entire production process, starting from the design phase, begins only after an order is received from the customer, and the product or service is designed based on specific customers' requirements; manufacture to order is instead a method according to which the design is pre-defined but the production starts only after the receipt of an order, and assembly to order is a method according to which some components are pre-produced and only assemble after the receipt of an order; finally, make to stock entails that the production process occurs independently from actual order from a customer. Understanding the differences among these production methods, it could be hypothesized that the preference for the first two production methods is related to the fact that as seen above the majority of clients are actually in the B2B segment, and may therefore have more specific needs that the companies must tailor their offering to. Looking instead at the production layout adopted (Graph 3.13), what emerges is that the most common layouts adopted by the sample of firms are the functional layout (42%) and the line layout (38%), while cell layouts and fixed layouts are not as common (13% and 8% respectively of the sample firms).

3.23 - Production methods adopted, by sales ($n^S=343$)



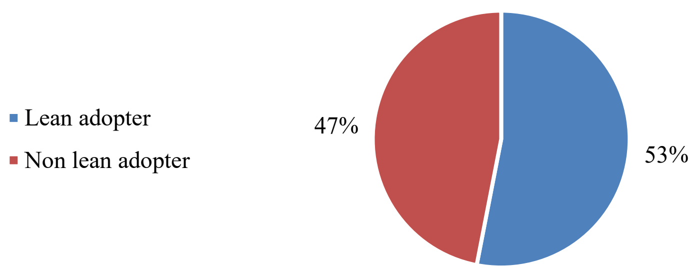
3.24 - Production layout adopted ($n^S=335$)



3.2.1 – Overview of lean adoption

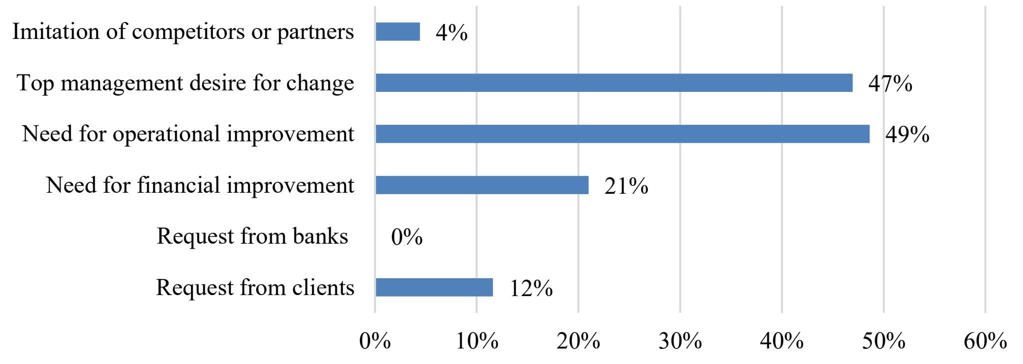
The survey also contained a section focused on gathering data regarding lean implementation in the sample firms. The first useful insight on this topic is the amount of lean adopters in the sample (Graph 3.25): firms who self-identified as lean adopters, because they stated to adopt at least one lean practice, were 182, or 53% of the sample.

3.25 - Distribution of lean adopters ($n^S=343$)

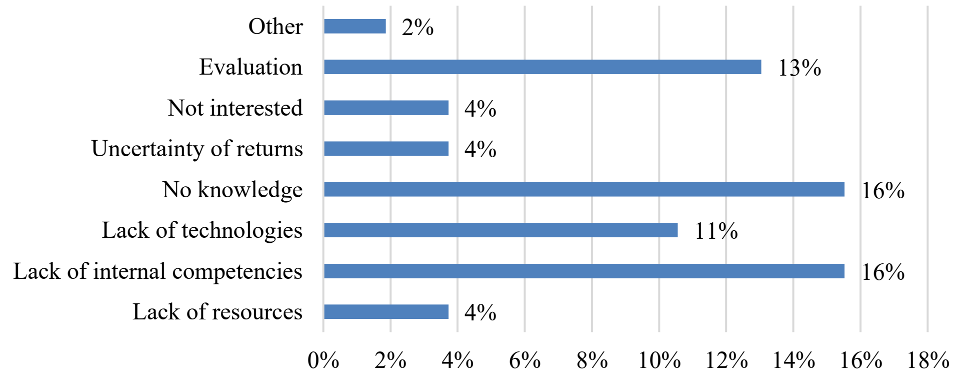


The survey also investigated the motivations behind the decision to adopt lean practices, and also on the opposite the possible reasons behind non-adoption. What emerged were two main drivers of lean transformations (Graph 3.26): the first is a perceived necessity for improvement of the firm performance, either on the operational level or on the financial level; the second is a desire for change supported by the top management. Request from clients and partners are also possible influences, as is the imitation of competitors, although less frequently. As for the companies who stated not to adopt lean, the main reasons (Graph 3.27) appear to be either a lack of specific knowledge, a lack internal competencies or a lack technologies.

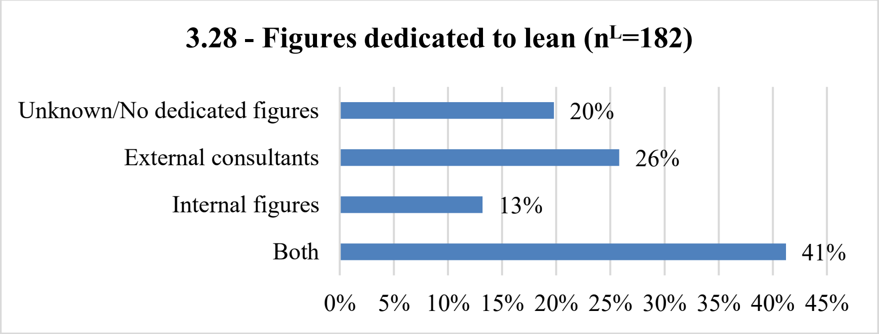
3.26 - Motivations behind lean adoption (n^{L}=182)



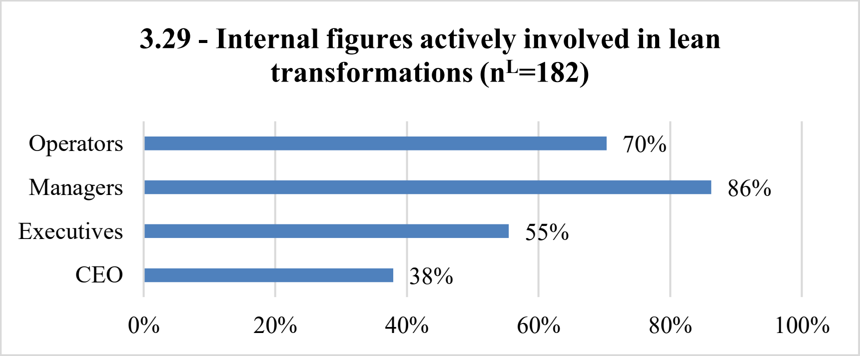
3.27 - Main reasons behind non-adoption (n^{NL}=162)



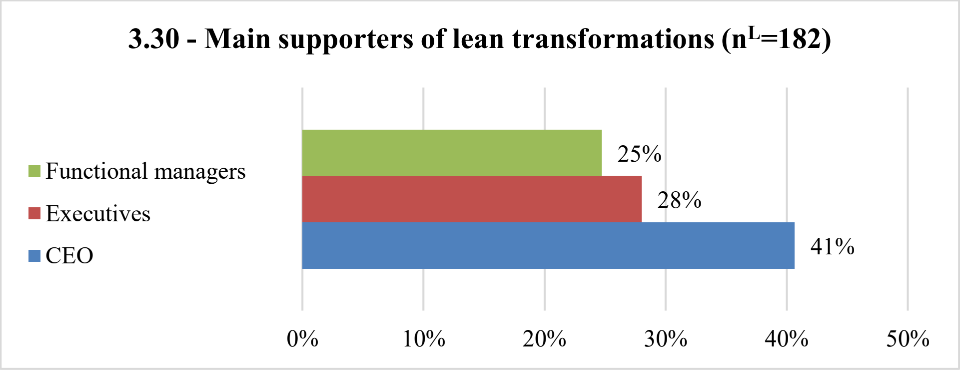
Further questions were present for the lean adopters, investigating specific aspects of their lean adoption. Two questions investigated the involvement of internal or external figures in lean transformations; the results (Graph 3.28) showed that 41% of lean firms in the sample affirm to have both internal figures and external consultants involved in the implementation of lean techniques, while the remaining firms rely either only internal figures (13%) or only external figures (26%), and a 20% of firms doesn’t have either. Focusing more specifically on internal figures (Graph 3.29), managers appear to be the category most actively involved in lean activities (stated by 86% of lean firms), with operators following them (70%). Executives and CEOs appear to be less frequently actively involved (respectively 55% and 38%); however, they are considered to be the main supporters of lean transformations, by respectively 28% and 41% of the firms (Graph 3.30).



3.28 - Figures dedicated to lean (n^L=182)

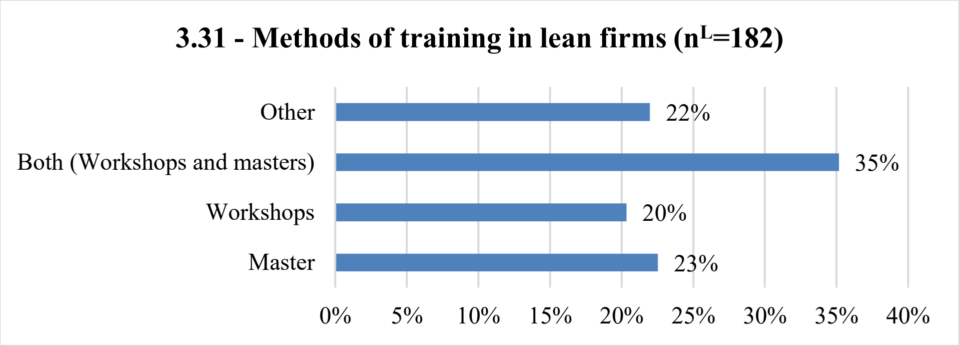


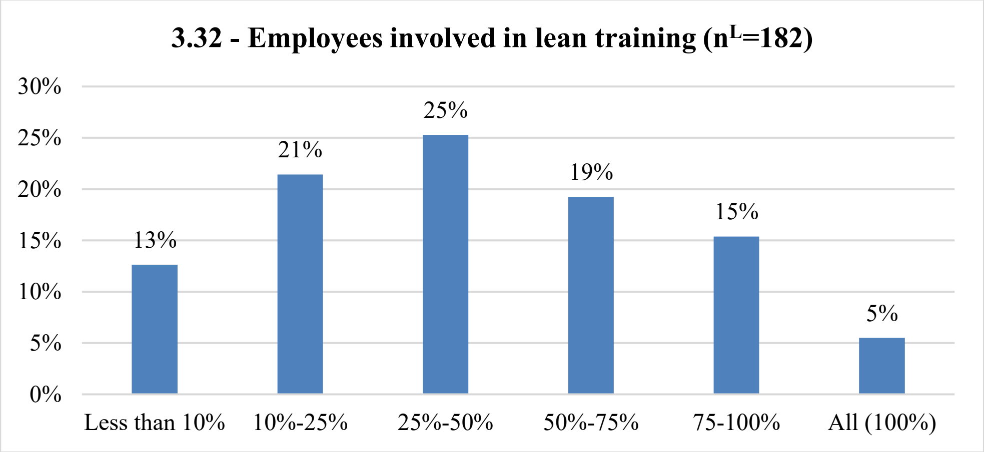
3.29 - Internal figures actively involved in lean transformations (n^L=182)



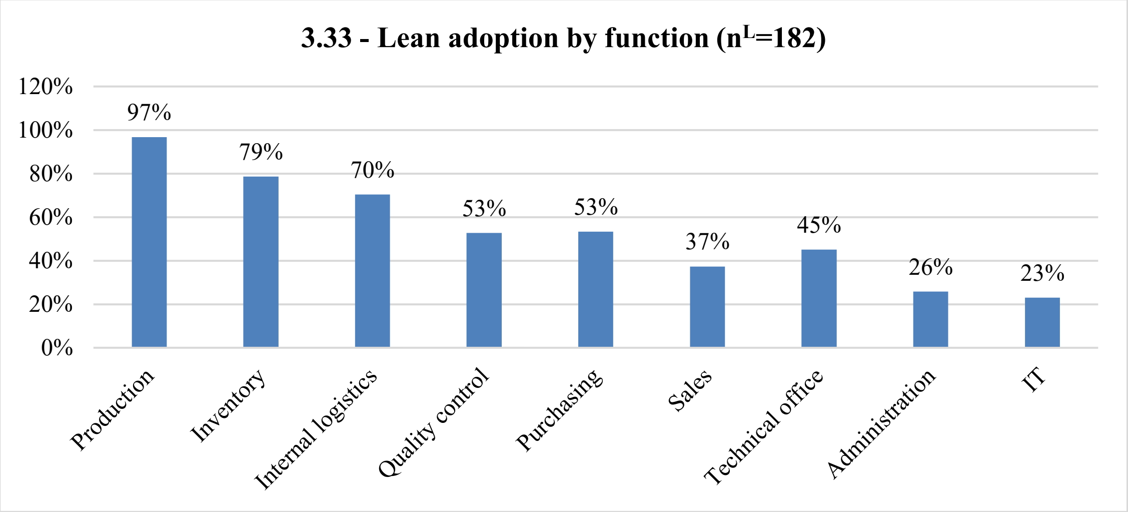
3.30 - Main supporters of lean transformations (n^L=182)

As observed before (Graph 3.27), many companies claimed to not adopt lean for a lack of knowledge and competencies. In fact, performing lean transformations and involving employees requires the acquisition of specific competencies, and therefore a certain extent of training and formation is necessary. In the sample firms, training is usually provided through workshops and masters, and frequently employing both methods (35%), while 22% of firms use alternative methods, usually in collaboration with external consultants (Graph 3.31). However, in many firms training involves only a percentage of employees (Graph 3.32), more frequently between 10%-25% (24% of firms) or between 25%-50% (25%), although it's worth to mention that there is a minority of firms that involve more than 75% of workers or even all of their employees in the various training activities (respectively 16% and 5%).

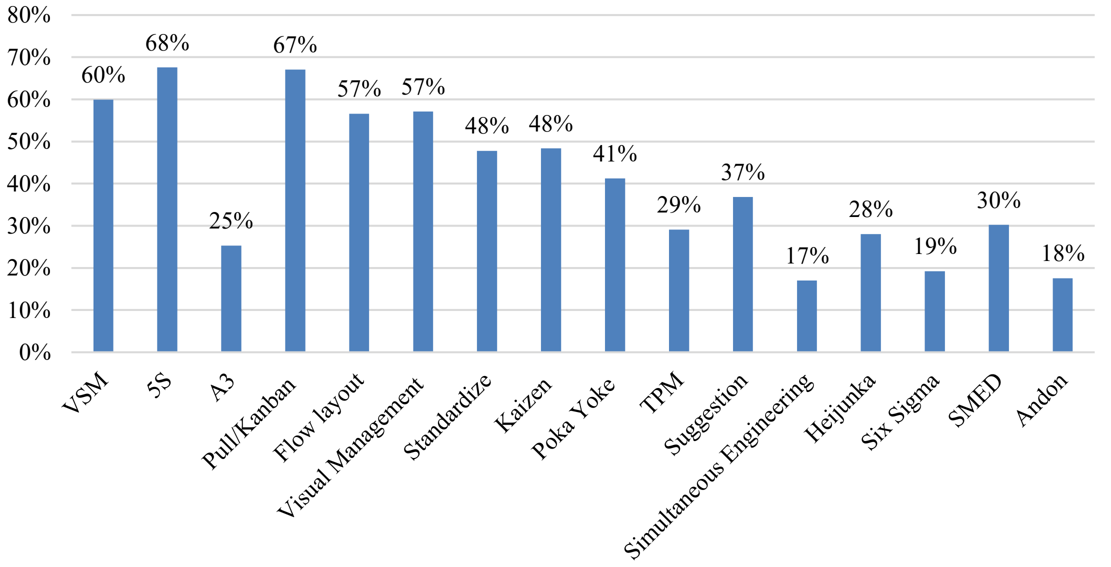




This aspect is possibly related to the fact that lean is generally not implemented in every functional area of firms (Graph 3.33). Considering as a criteria the implementation of at least one practice, the survey provided information regarding the functions in which lean is implemented. The results show that the area in which lean is most implemented is production (97% of firms), followed by inventory and internal logistics (respectively 79% and 70% of firms); quality control and purchasing are also common areas for 53% of firms, while it appears still less adopted in other areas such as sales (37%), administration (26%) and IT (23%).

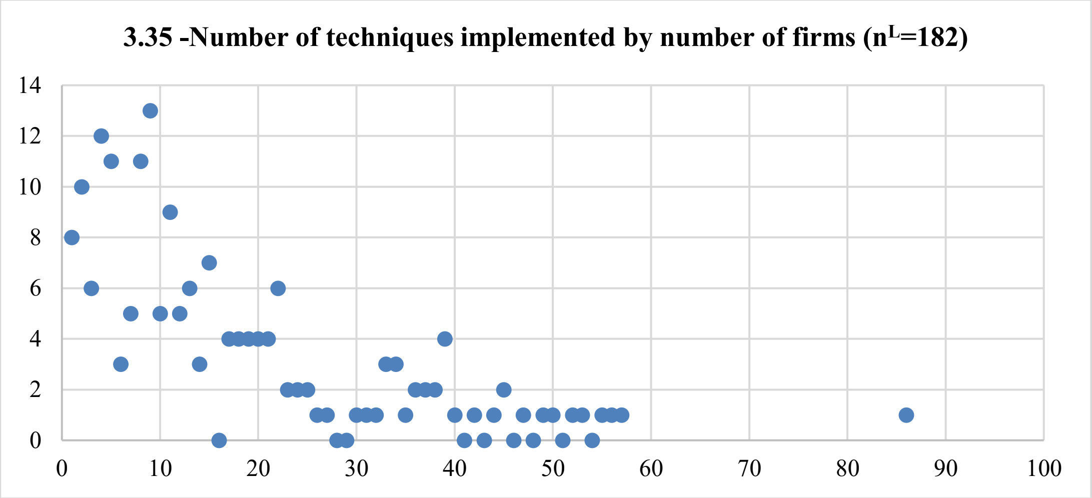


The different practices adopted can also be considered. Considering 16 lean practices (Graph 3.34), it appears that the most common are 5S (68%) Kanban (67%). This result is not surprising, since these practices are generally regarded to be among the first steps of lean transformations, given their visual nature, and therefore will be likely adopted even by firms who have recently began their lean introduction. Other popular practices include Value Stream Mapping (60%), Flow layout and visual management (57%), while the remaining practices were adopted by less than 50% of the firms considered.

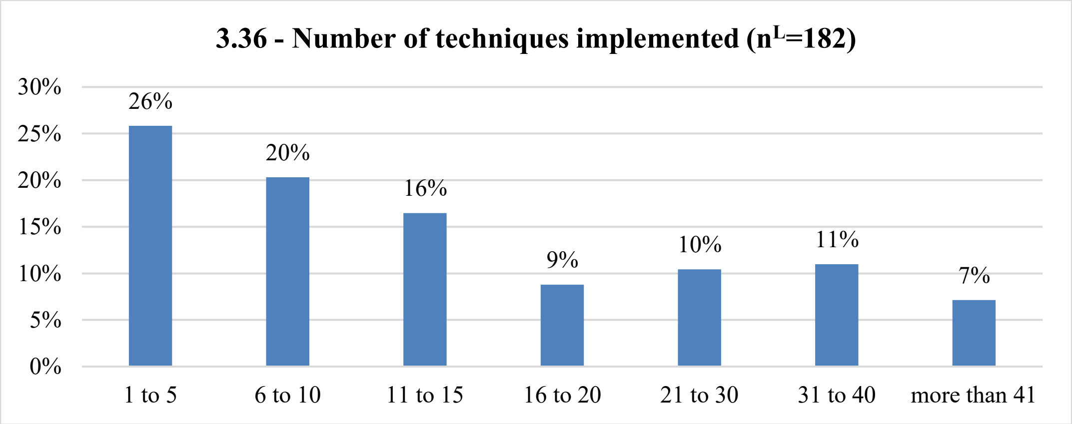


3.34 - Lean adoption by technique (n^L=182)

While discussing the techniques adopted, it should be considered that even though so far a company has been considered lean if it implemented at least one lean practice, the actual number of practices implemented differs significantly between the various firms in the sample. Graph 3.35 below shows the distribution of number of firms for each number of techniques implemented simultaneously, while Graph 3.36 divides them in classes. While the number of practices ranges from 1 to 57, with an outlier at 86, an observation that emerges clearly is that almost half of the firms considered implement a very limited number of practices, 10 or less, with 26% implementing even less than 5. Since many authors have argued that benefits from lean implementation only occur through a comprehensive transformation (Fullerton et al., 2003; Losonci and Demeter, 2013), it can be interesting to observe if there are differences between low-implementers, which could be called beginners since they are at the beginning of their lean transformation, and more advanced implementers. Moreover, the comparison can provide insights regarding which specific practices and functional areas are chosen as first steps in lean implementations.

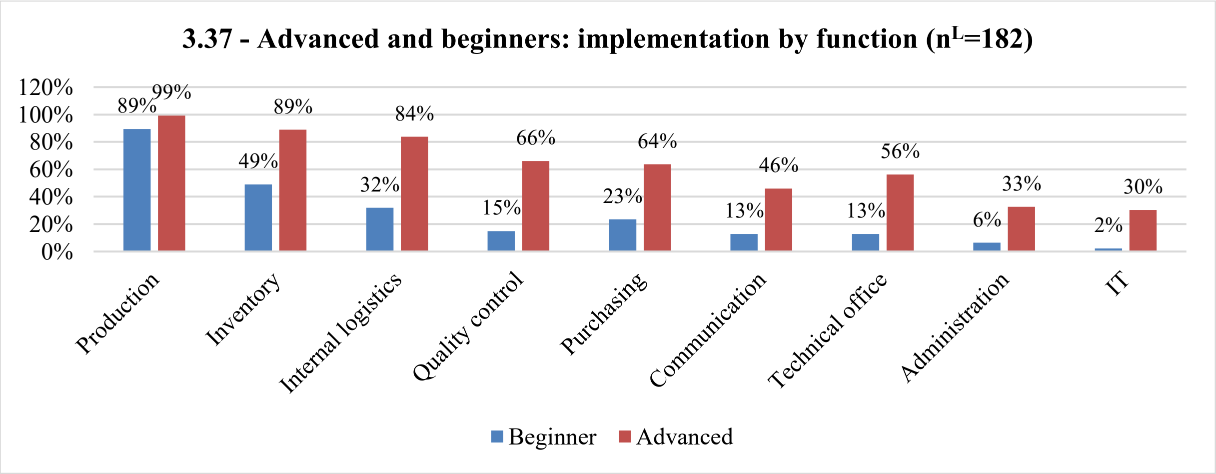


3.35 -Number of techniques implemented by number of firms (n^L=182)

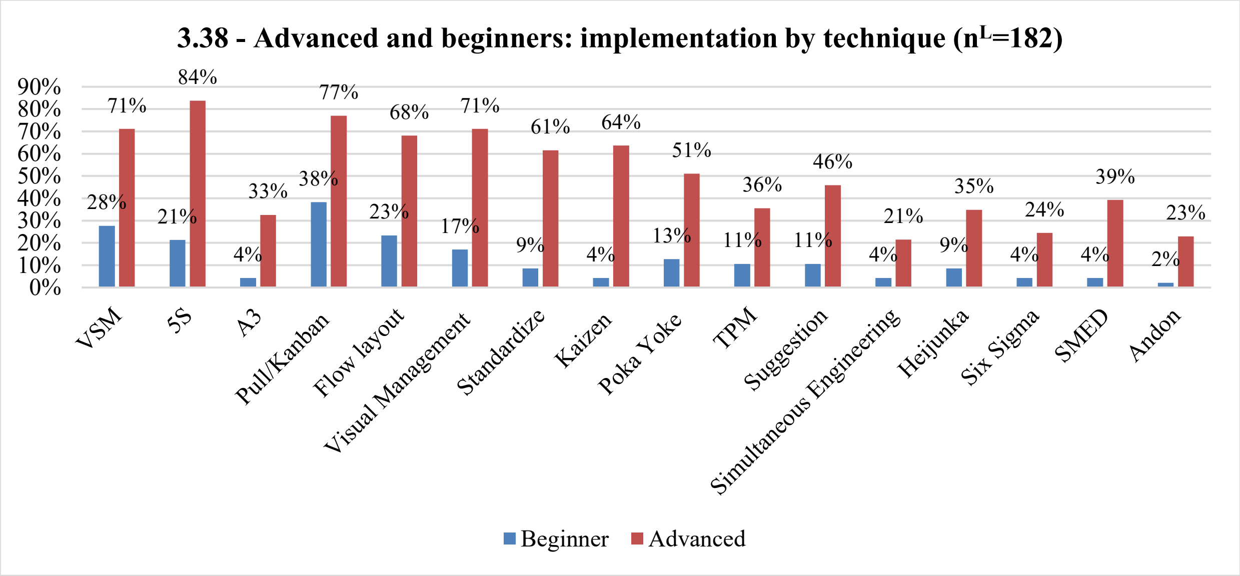


3.36 - Number of techniques implemented (n^L=182)

The graph below shows the different distribution of functions. It appears clear that beginner firms tend to focus their efforts on production (89%) inventory (49%) and internal logistics (32%); this is an expected result, since they are the first areas in which lean transformations usually occur, and they are also the areas on which more advanced adopters tend to focus their efforts. Looking instead at the type of practices adopted, the beginners seem to be focused on Pull, Value stream mapping, flow layout and 5s, while the advanced firms show a wider range of practices adopted.

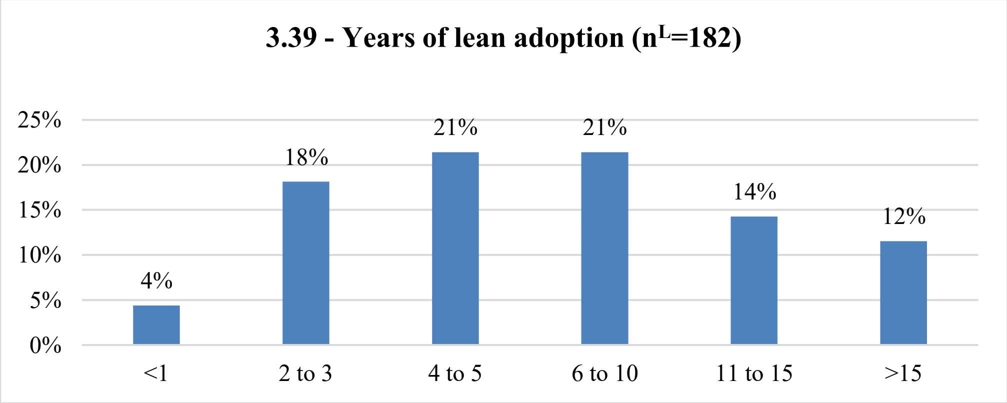


3.37 - Advanced and beginners: implementation by function (n^L=182)



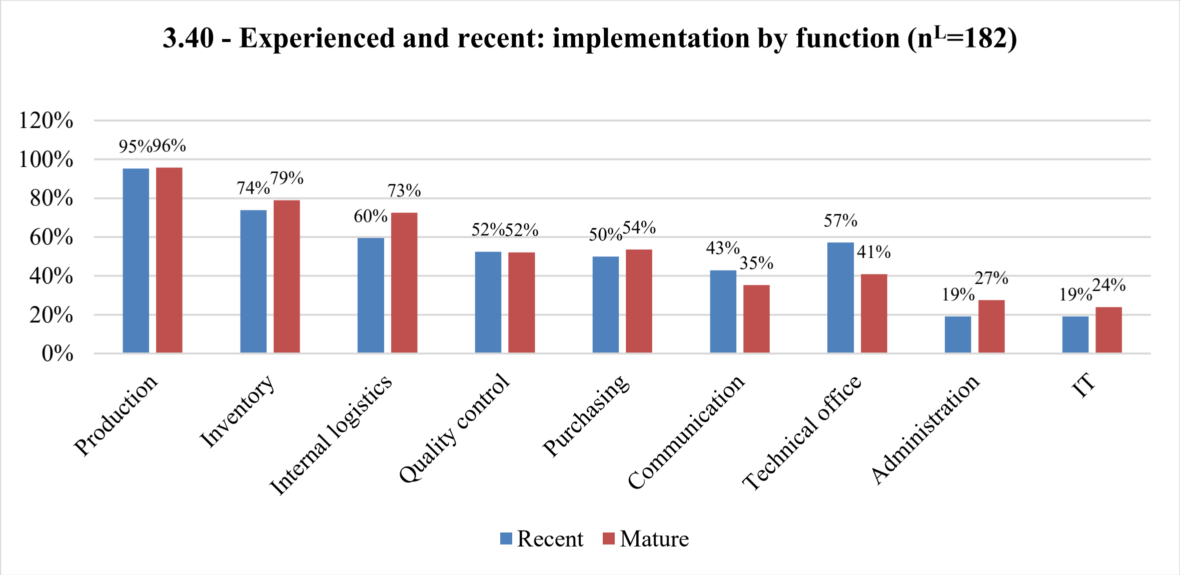
3.38 - Advanced and beginners: implementation by technique (n^L=182)

Another method to consider the extent of lean implementation could be to look at the number of years for which firms have been implementing lean. What appears by looking at the firms in the sample, is that the adoption of lean (computed as of 2019) seems overall recent, with 22% having adopted lean practices for less than 3 years, an additional 21% for 4 to 5 years and 21% for a time between 6 and 10 years (Graph 3.39). However, there is also a 26% of experienced implementers, who have been lean adopters for more than 10 years.

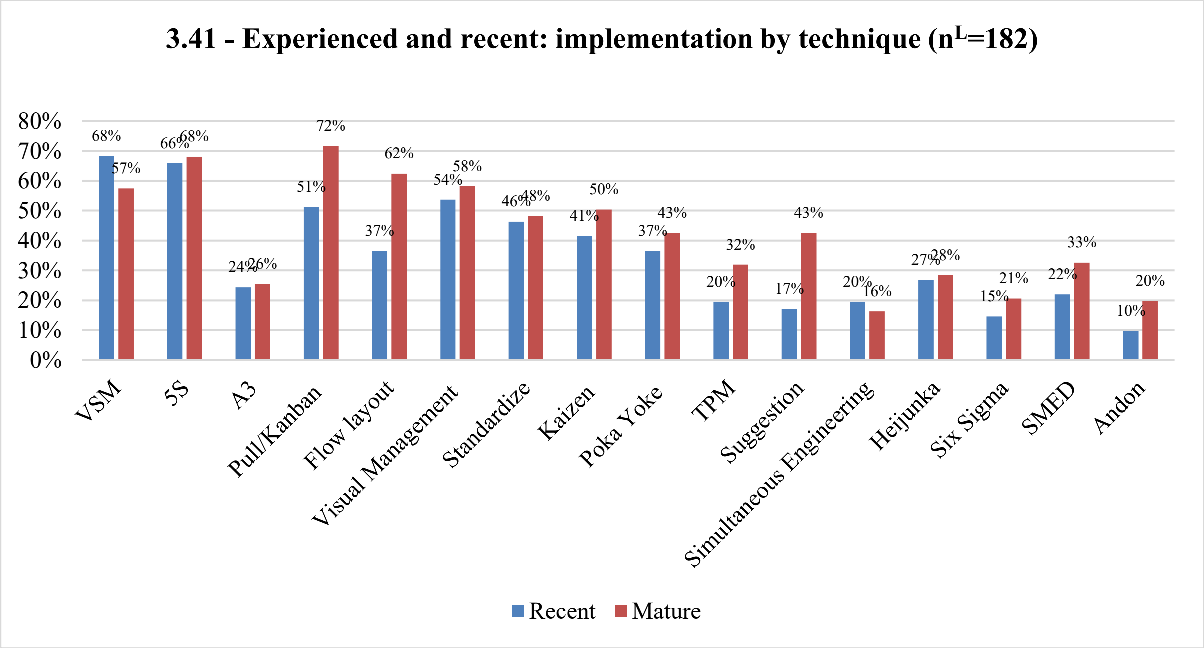


3.39 - Years of lean adoption (n^L=182)

It could be interesting to observe whether a the difference can be found between the firms who have only started to implement lean recently (1 to 3 years) and those who have been implementing for at least 3 years. The graphs below show the distribution of lean adoption, by function and by techniques, for recent and mature lean adopters. However, differently from what was observed for the extent of implementation (in terms of number of techniques), it doesn't appear that recent adopters are focused on certain functions or certain techniques. Therefore it could be hypothesized that a recent implementation doesn't necessarily translate to a lower intensity of implementation.



3.40 - Experienced and recent: implementation by function (n^L=182)



3.41 - Experienced and recent: implementation by technique (n^L=182)

3.4 - Identification of periods of crisis at industry level

Having identified the sample and described some of its main features, the focus should now shift back to identify periods of turbulence. For the six industries selected (Table 3.1), a brief analysis was conducted to identify which among them experienced periods of evident turbulence. First of all, having established that the main disruptive event in the period available was related to the 2008 crisis, the financial information regarding three profitability indicators was divided in two five-year periods: the years from 2009 to 2013, which represent the years following the disruption related to the 2008 crisis; and the years from 2014 to 2018, which are expected to represent a period of relative stability. The choice of considering five-year periods is supported by literature, as previous works have employed five-year windows to measure variability in industries, since the length of the period allows to consider a medium term view (Azadegan et al., 2013).

For each of the six industries selected, the average value and the standard deviation[6] of the following indicators were calculated in each of the two time periods: ROA, ROS and ROI, as shown in tables 3.2 to 3.4. The underlying assumption is that in a period of crisis we expect to find lower average values of the indicators when compared with a period of relative stability; at the same time the standard deviation, particularly if considered in relative terms to the average value computed, should be high because of the larger variations caused by the disruptions present in a dynamic environment. In the following pages the results are reported, and for each indicator the periods of higher variability are identified.

The findings for ROA, ROS and ROI (Table 3.2, 3.3, 3.4) are commented together as the results appear to be correlated. The comparisons show lower average values in the 2009-2013 period for each industry, and also show higher standard deviation in the same period, with the only exception of the ATECO 20-22 industry in all the three cases. Instead of looking at the standard deviation in absolute terms, it could be more meaningful to consider it relatively to the average in the period; for this purpose, the coefficient of variation[7] was computed, shown in the last two columns. What emerges is that for the six industries considered, the relative standard deviation of revenues was particularly high for the ATECO 24-25, ATECO 27, ATECO 28 and ATECO 31 industries in the 2009-2013 period: for each of these four industries the standard deviation was equal to more than 20% of average ROA, ROS and ROI respectively, suggesting a situation of turbulence in the period considered. Moreover, considering the criteria of 20% both ROA and ROS also show high variability for the ATECO 31 industry in 2014-2018, while only ROA also shows it for ATECO 27 in the same period.

Table 3.2 – Average and standard deviation of industry ROA

Industry	Average 09-13	Average 14-18	S.D. 09-13	S.D. 14-18	CV 09-13	CV 14-18
ATECO 10-11	6,43	7,09	1,04	0,65	16%	9%
ATECO 20-22	4,57	6,87	0,49	1,03	11%	15%
ATECO 24-25	4,21	6,15	1,75	0,53	42%	9%
ATECO 27	3,66	5,17	1,44	1,11	39%	22%
ATECO 28	5,78	6,95	1,39	0,63	24%	9%
ATECO 31	4,62	5,88	1,85	1,32	40%	22%

---

[6] The Standard Deviation is a metric of dispersion, employed to express to which extent the values in a group deviate from the mean value of the group. It's equal to the square root of the variance.

[7] The coefficient of variation is computed as the ratio between the standard deviation and the mean of a sample of values. It is a measure employed to express relative variability.

Table 3.3 – Average and standard deviation of industry ROS

Industry	Average 09-13	Average 14-18	S.D. 09-13	S.D. 14-18	CV 09-13	CV 14-18
ATECO 10-11	5,25	6,31	0,69	0,48	13%	8%
ATECO 20-22	3,68	5,63	0,43	1,14	12%	20%
ATECO 24-25	3,83	5,81	1,32	0,57	34%	10%
ATECO 27	2,66	4,26	1,06	0,46	40%	11%
ATECO 28	4,65	6,24	1,18	0,41	25%	7%
ATECO 31	2,76	3,84	1,30	0,85	47%	22%

Table 3.4 – Average and standard deviation of industry ROI

Industry	Average 09-13	Average 14-18	S.D. 09-13	S.D. 14-18	CV 09-13	CV 14-18
ATECO 10-11	8,82	10,17	1,21	0,75	14%	7%
ATECO 20-22	5,61	9,12	0,69	0,79	12%	9%
ATECO 24-25	6,29	8,27	1,59	0,70	25%	9%
ATECO 27	6,14	8,53	1,66	1,19	27%	14%
ATECO 28	7,32	10,19	1,36	1,02	20%	10%
ATECO 31	7,70	8,52	2,73	1,05	35%	12%

Considering these observations, Table 3.5 summarizes the results. Specifically, the table includes the coefficients of variations computed for each indicator in the two time periods, and the most turbulent periods and industries discussed above are indicated in red by the table; To provide a comparison, the table also identifies for each indicator the industries and periods characterized by the lowest variability, indicated in green. The following criteria were used to distinguish periods of stability and turbulence:

- A coefficient of variation > 20% indicates a period of turbulence
- A coefficient of variation <10% indicates a period of stability.

What appears from this data is that among the six industries considered there are four industries that seem to have been clearly impacted severely by the periods of turbulence (ATECO 24-25, 27, 28 and 31), while the remaining two industries (ATECO 10-11 and ATECO 20-22) seem to have operated in conditions of relative stability in both time periods.

Table 3.5 – Periods of turbulence and stability in six industries

🟩 *stability*
🟥 *turbulence*

	ROA		*ROS*		*ROI*	
	CV 09-13	**CV 14-18**	**CV 09-13**	**CV 14-18**	**CV 09-13**	**CV 14-18**
ATECO 10-11	16%	🟩 9%	13%	🟩 8%	14%	🟩 7%
ATECO 20-22	11%	15%	12%	20%	12%	🟩 9%
ATECO 24-25	🟥 42%	🟩 9%	🟥 34%	🟩 10%	🟥 25%	🟩 9%
ATECO 27	🟥 39%	🟥 22%	🟥 40%	11%	🟥 27%	14%
ATECO 28	🟥 24%	🟩 9%	🟥 25%	🟩 7%	🟥 20%	🟩 10%
ATECO 31	🟥 40%	🟥 22%	🟥 47%	🟥 22%	🟥 35%	12%

3.5 – Overview of performance in industry sub-samples

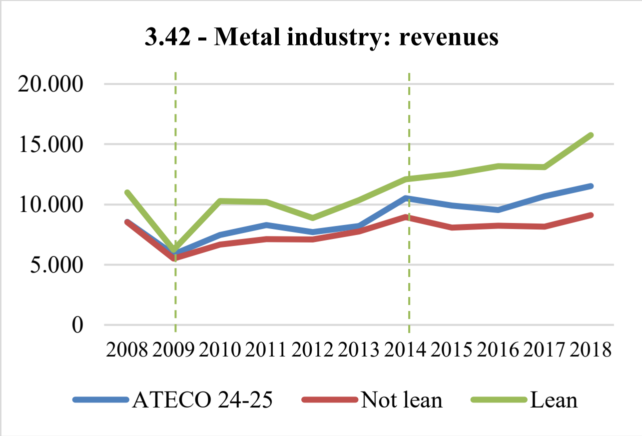
At this point, a possible first step is to observe whether at industry level a difference in performance can be found among lean adopters and non-adopters, specifically in the identified periods of turbulence. In order to do this, we can look again at the same indicators of financial performance employed in paragraph 3.4: ROA, ROI and ROS; in this case, a graphical overview of revenues is also provided. In this case the indicators are computed again, but for each single industry rather than for the whole sample, and within each industry distinguishing among lean adopters and outsiders. In addition, to provide more reliable results the information for lean adopters has been included for each of the two periods only considering those firms that were already implementing lean before the beginning of the period (therefore, lean firms were included only if they were implementing lean respectively before 2009 for the 2009-13 period and if they were implementing lean before 2014 for the 2014-18 period). The first part of the paragraph is focused on the four industries that experienced a period characterized by significant variability in revenues and performance, while the second part provides an overview on the two firms that appeared relatively more stable.

3.4.1 – Performance during periods of turbulence

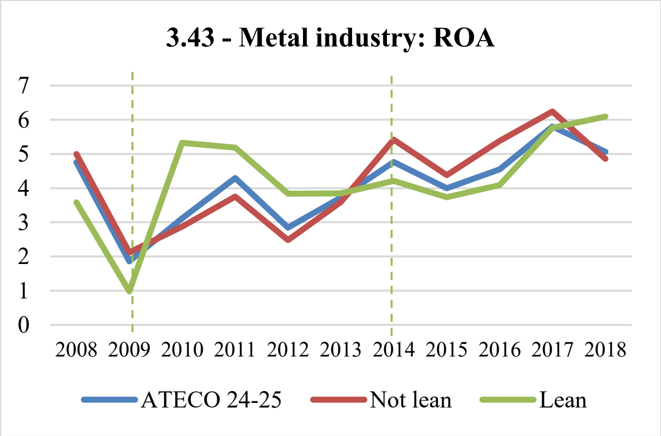
The preliminary analysis investigating industry average of revenues and performance indicators allowed to identify four industries that were characterized by high variability in at least one period for at least four out of five indicator: the Metal and steel industry, the Electrical equipment industry and the Machinery industry and the Furniture industry. In the rest of the paragraph the performance in each of these industries will be analyzed graphically to identify possible differences among lean adopters and non-adopters.

Metal industry – ATECO 24 and 25

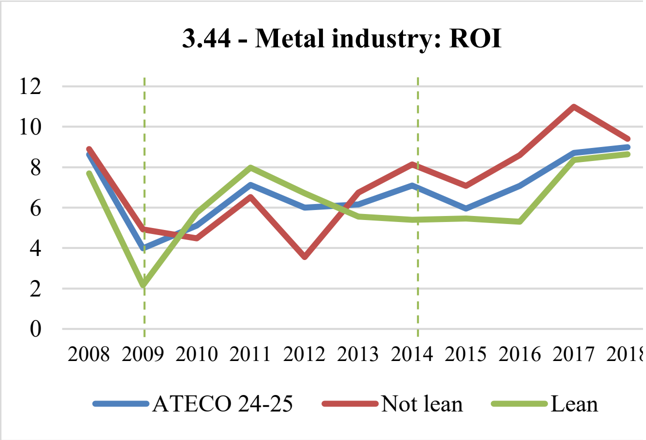
The first series of graphs is focused on the Metal and steel industries (identified by ATECO codes 24 and 25), which present a particularly turbulent period in the years 2009-2013 for all indicators. Looking at the revenues, lean firms appear to have consistently higher revenues over time compared with outsiders, including in the period of crisis; however, they also show a significant decline in 2009 and again in 2012, which suggests that they were indeed impacted negatively from the crisis just as much as not-lean adopters. The decline in 2009 is also observed for all the other indicators of performance. Lean firms in this industry then appear to recover rapidly, and maintain a better performance than their non-lean counterparts in the turbulent years immediately following the crisis. However, it's interesting to observe that the indicators show a worsening performance of lean firms in the second period, with outsiders showing a better performance starting from the years 2013-2014. This is opposed to what was observed for the entire sample, and the reason is unclear, although a possible hypothesis is that it could be due to an increment in the number of new firms that started to implement lean.



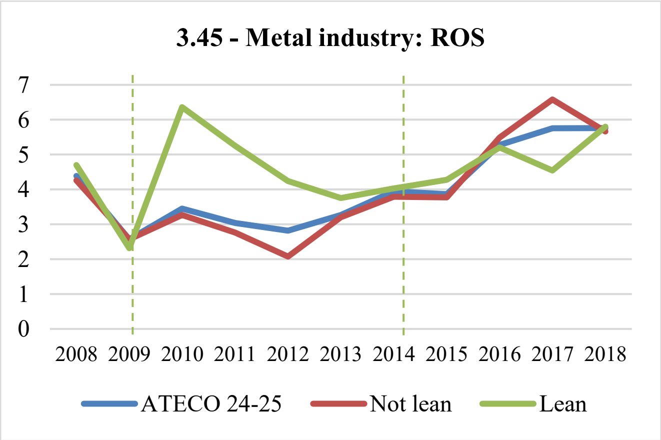
3.42 - Metal industry: revenues



3.43 - Metal industry: ROA



3.44 - Metal industry: ROI

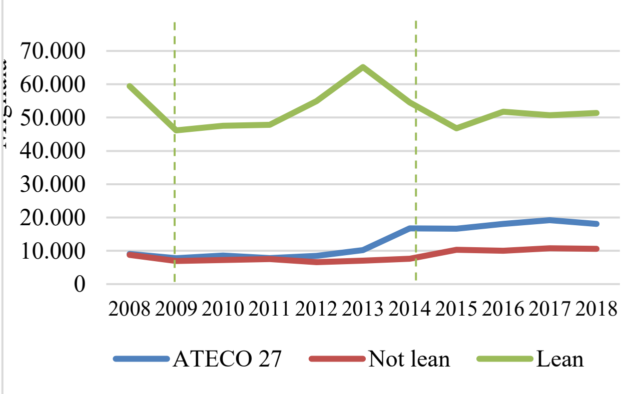


3.45 - Metal industry: ROS

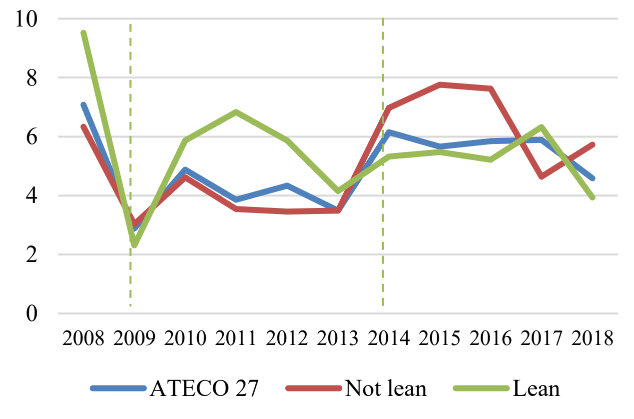
Electrical equipment industry – ATECO 27

The next series of graphs is focused on the Electrical equipment industry, for which all the indicators previously observed suggest a period of turbulence in the 2009-2013 period. Revenues show a consistently superior performance of lean firms in this industry, but it could be due to firm size. As for the other indicators, the situation is more unclear: both lean firms and outsiders were impacted negatively in 2009, to a similar extent; however, in the years following the disruption it isn’t possible to identify a clear difference in performance: lean firms do show a better performance in years 2010-2013 (for ROA, ROI, ROS), suggesting a rapid recovery from the crisis and a better resiliency in a period characterized by variability. However, the same can’t be stated for the second period, where the pattern over the years is fragmented and unclear for all indicators.

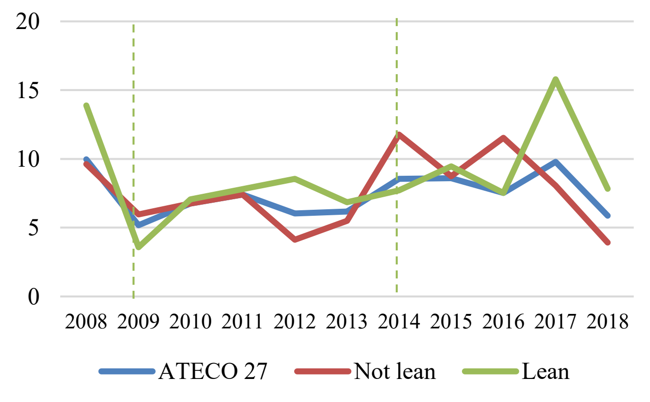
3.46 - Electronic appliances industry: Revenues



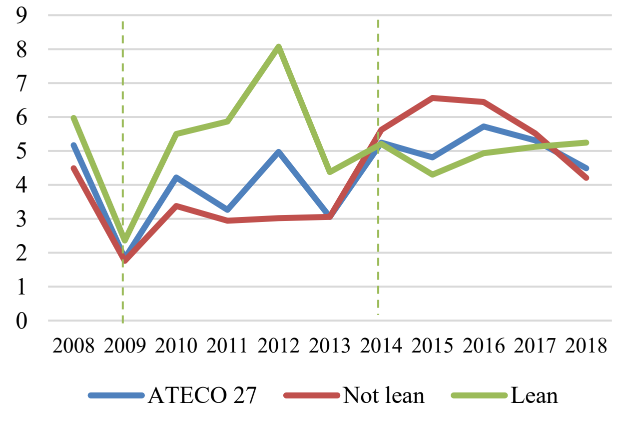
3.47 - Electronic appliances industry: ROA



3.48 - Electronic appliances industry: ROI

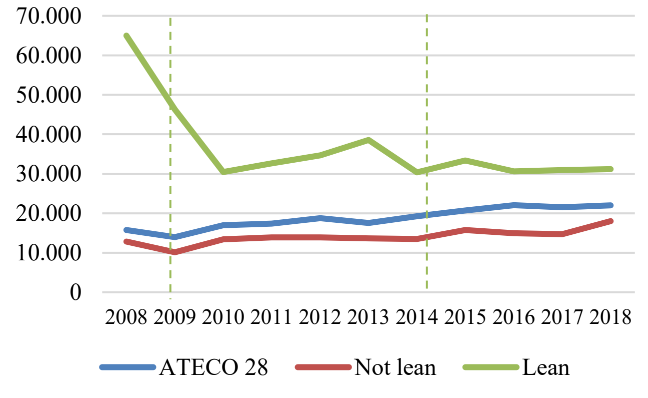


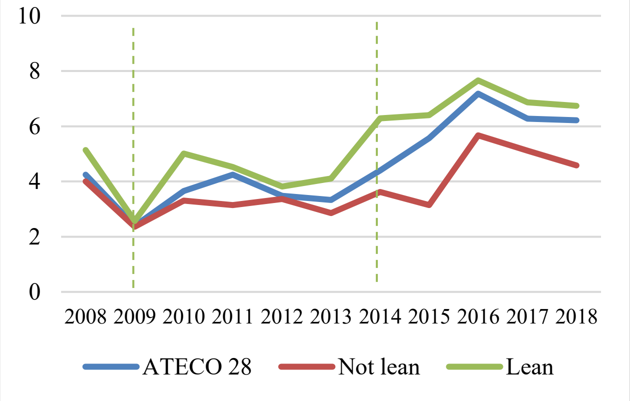
3.49 - Electronic appliances industry: ROS

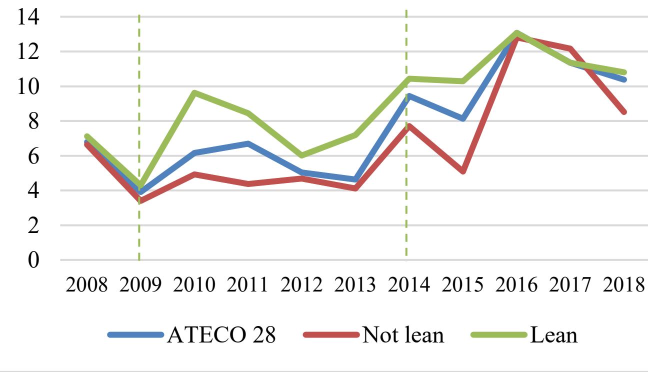


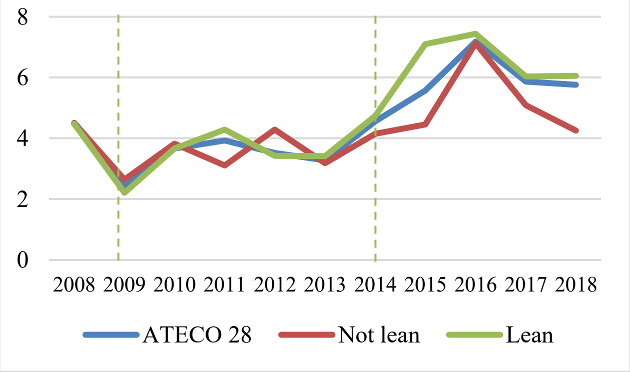
Machinery industry – ATECO 28

The next series of graphs is focused on the Machinery industry, identified by ATECO 28. Revenues show a consistently superior performance of lean firms, but once again this could be related to firm size. As for the other indicators, the situation is more unclear: both lean firms and outsiders were impacted negatively in 2009, to a similar extent; in the years immediately following the disruption, lean firms showed a better recovery (in terms of ROA, ROI), followed by a generally better performance in the subsequent period. However, looking instead at ROS there aren't consistent differences in performance to be observed between lean and non-lean firms, neither positively nor negatively.


3.50 - Machinery industry: Revenues

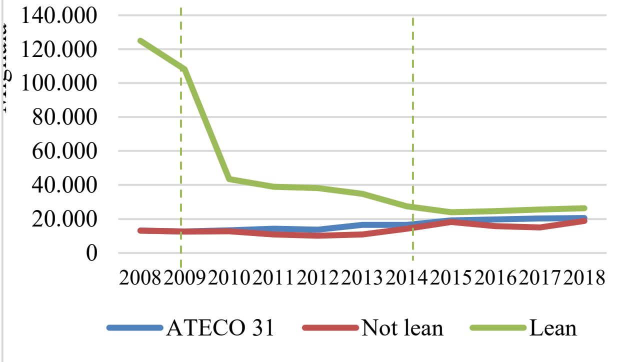

3.51 - Machinery industry: ROA


3.52 - Machinery industry: ROI

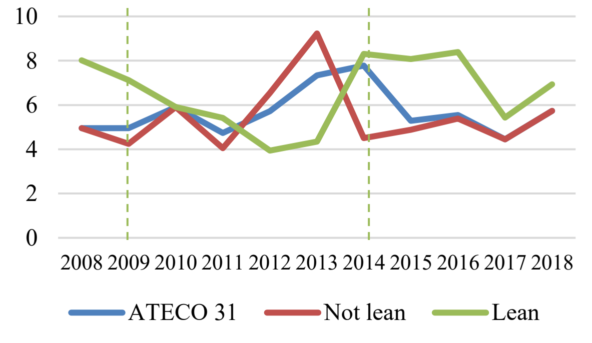

3.53 - Machinery industry: ROS

Furniture industry – ATECO 31

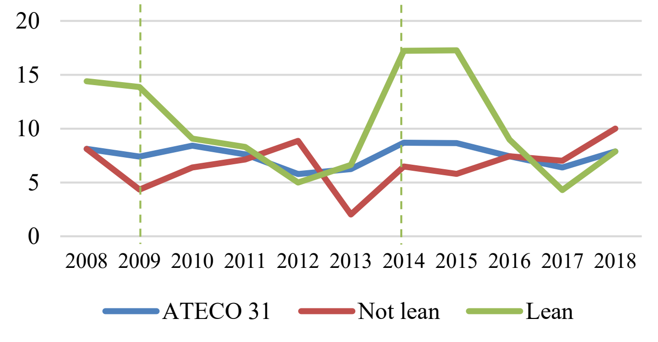
The furniture industry appears to have turbulent in the first period. While once again revenues of lean firms are superior to those of outsiders in both periods, the fragmented pattern of the indicators in the graphs below also doesn't allow to understand clearly whether or not there is a consistent difference in performance among lean adopters and non-adopters: in fact, all the indicators show a better performance of lean adopters in 2009, but in the years between 2010-2014 only one indicator shows a better performance (ROS), while the pattern is unclear for ROA, ROI. However in the 2014-18 period the performance of lean firms does appear superior to outsiders, although with exceptions particularly in 2018.



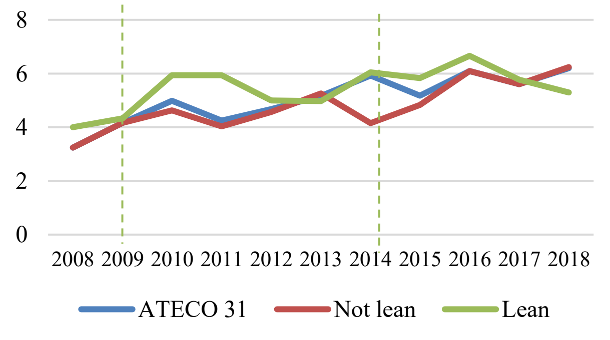
3.54 - Furniture industry: Revenues



3.55 - Furniture industry: ROA



3.56 - Furniture industry: ROI



3.57 - Furniture industry: ROS

To conclude, the graphical comparison of performance indicators doesn't provide clear evidence in favor of a consistently superior performance of lean firms in the period following a crisis; however, at the same time it also doesn't provide evidence supporting a consistently worse performance, as in all cases the patterns appear quite fragmented. In all industries lean firms appeared negatively impacted in the year of the main crisis, 2009, just as much as the outsiders. However, the values also suggest a rapid recovery in performance in the years immediately following the crisis, although the data are not sufficiently homogeneous to state it with certainty.

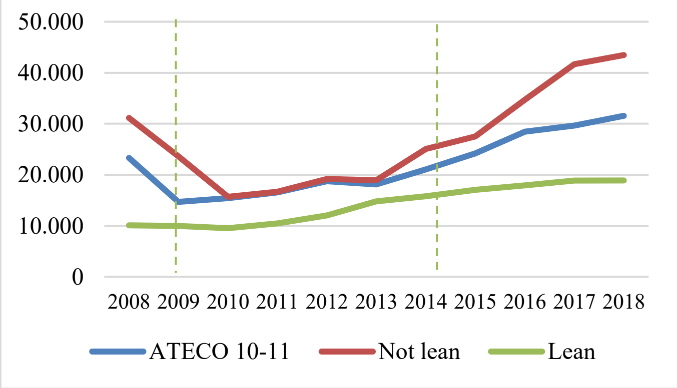
3.4.2 – Performance in periods of relative stability

Among the six industry sub-samples considered, the food and beverage industry (identified by ATECO codes 10 and 11) and the Chemical industry (identified by codes 20 and 22) appear to have been relatively more stable in all periods. In the last part of the chapter the graphical trend of their indicators of financial performance will be observed, to understand if in relatively stable industries a difference in performance appears more clearly.

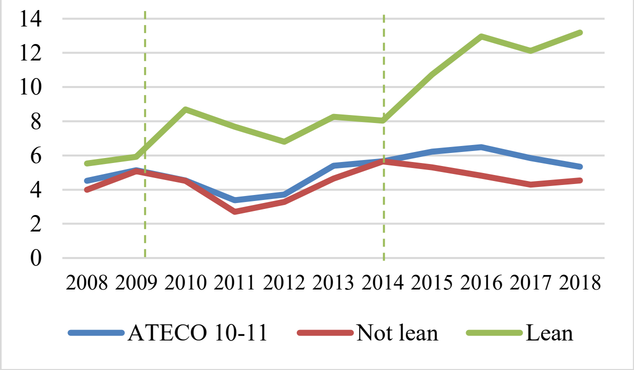
The food and beverage industry - ATECO 10 and 11

Differently from what was observed before, in this industry the revenues for lean firms appear to be lower than those of outsiders; however, once again this indicator is not particularly informative. What is more important to observe is that for the remaining indicators of performance lean firms show a consistently better trend, showing a difference of more than 2 points compared with outsiders for most indicators throughout the period. The only instances in which indicators show a negative downturn is ROI in 2009; however in both cases the decline was followed by a rapid recovery, superior to the trend for outsiders.

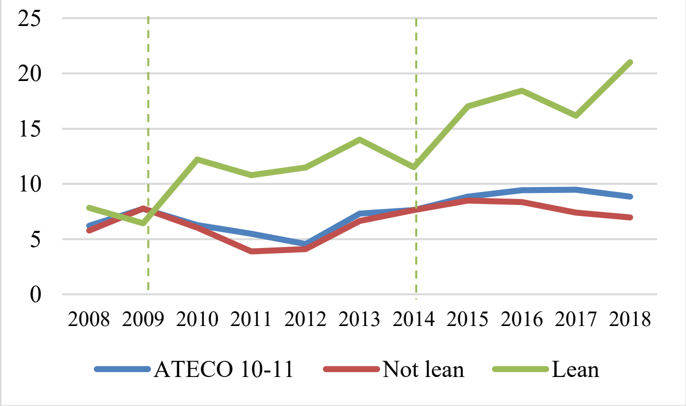
3.58 - Food and beverage: Revenues



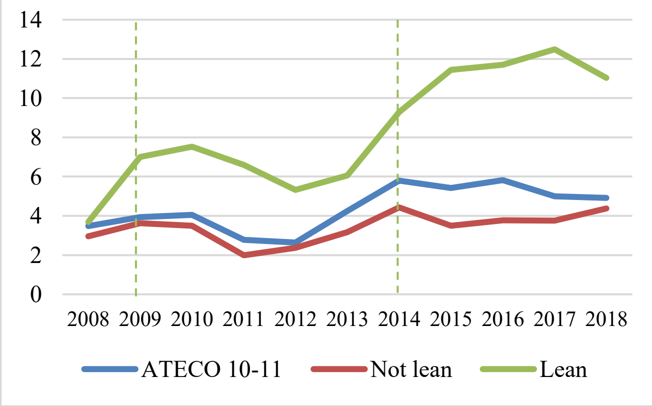
3.59 - Food and beverage: ROA



3.60 - Food and beverage: ROI

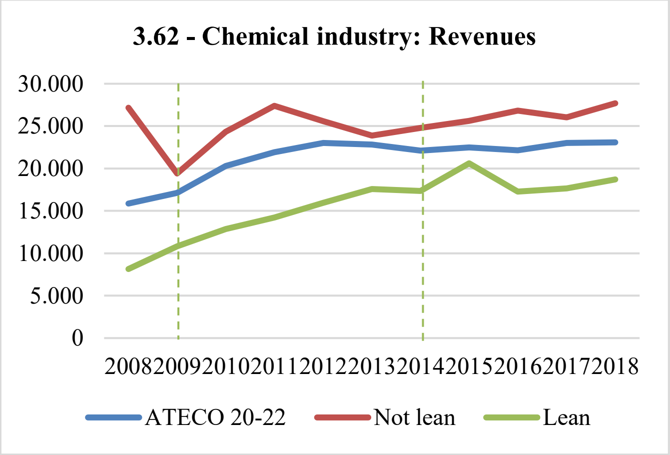


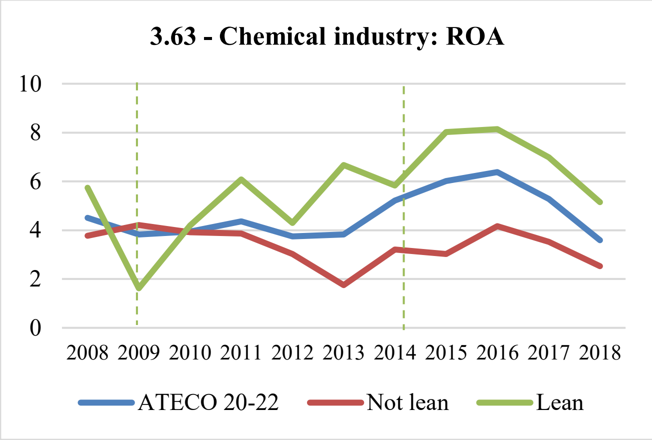
3.61 - Food and beverage: ROS

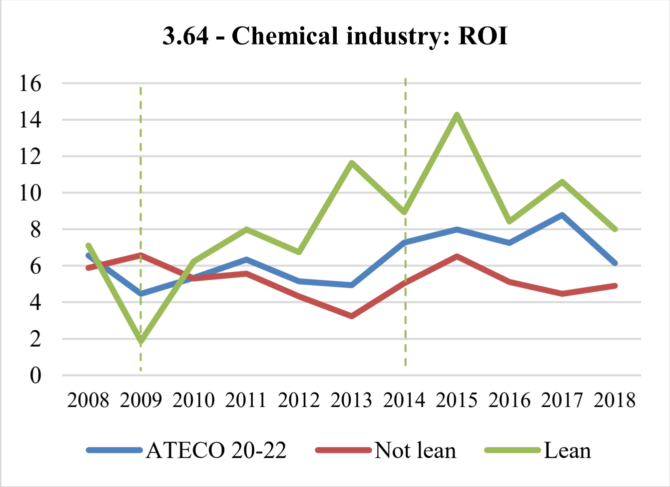


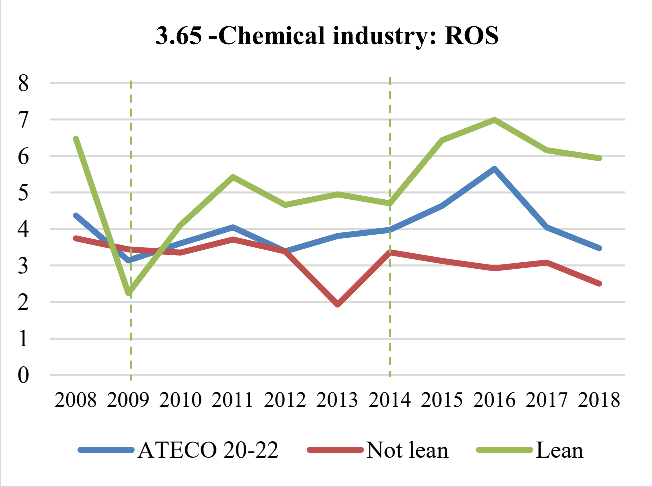
Chemical industry – ATECO 20 and 22

Similar observations can be made for the chemical industry. In this case as well, we find lower revenues of lean firms compared with those of outsiders, but an overall better performance as shown by other indicators: while lean firms show a particular decline in 2009 for ROA, ROI and ROS, worse than the industry average, they also show a rapid recovery in the following year and a superior performance against outsiders for the remaining years.









To conclude, the analysis in this chapter provided an overview of the main features of the firms in the dataset available. In the second part of the chapter, the focus was shifted on the identification of periods of high variability, which will be the starting point for the t-test analysis in chapter 4. Finally, some consideration were made through graphical comparisons, to identify possible linkages among lean adoption and financial performance, although the results were unclear, especially in the case of periods of high variability, highlighting the need for further analysis.

CHAPTER 4

T-TEST ANALYSIS

The previous chapter introduced some preliminary steps of analysis, with the purpose of identifying periods of turbulence and of relative stability within the industry sub-samples available. In conclusion it provided a graphical analysis of the performance of firms throughout a 10-year period, which did not however provide clear evidence of a difference in performance among lean adopters and outsider firms, neither in a positive nor in a negative direction. The following chapter attempts to go further through a more formal analysis.

The objective of the analysis that will be performed is to test whether the adoption of lean management has a positive impact on the financial performance of firms, an argument on which several studies in literature seem to agree, but especially whether this positive impact is retained when industries find themselves operating in situations of high variability, that arise for example following disruptions in the external environment. Establishing that the adoption of lean management can help sustain a superior performance not only in stable periods, but in relatively turbulent periods as well, would provide evidence in favor of positive a positive relationship between the adoption of lean practices and firm resilience.

For the purpose of this work, the resilience of firms will be assessed in terms of a superior financial performance. More precisely, in order to conduct the analysis three performance indicators have been employed: Return on Assets (ROA), Return on Sales (ROS) and Return on Investment (ROI). The choice of these three indicators was driven by their employment in previous literature studies that had investigated the impact of leanness on financial performance (Hofer et al., 2012; Azadegan et al., 2013; Galeazzo and Furlan, 2018). The underlying hypothesis is that it is expected that all of these indicators should be positively impacted by the adoption of lean.

The analysis will focus on a comparison of the mean values of these indicators, comparing lean adopters against outsiders, and testing the significance of possible difference in the means through a two-sample T-test analysis.

4.1 - T-Test Analysis on the means of performance indicators

The analysis reported in the following paragraph is based on a comparison of the mean values of three indicators of financial performance. A preliminary clarification on the sample is necessary: based on the considerations made in the previous chapter, the number of firms in the original sample was reduced, to include only the industries for which it was possible to identify periods of stability and of turbulence, which led to a sample of 263 firms, representative of six Italian manufacturing industries (Table 3.1). Furthermore, for the purpose of the t-test analysis only the specific periods for which it was possible to establish a condition of stability or turbulence were considered, as shown previously in Table 3.7. To proceed with the analysis, the firms were thus divided according to two criteria:

- Whether or not they experienced high variability during the time period considered.
- Whether or not they were lean adopters during the time period considered.

Table 4.1 shows this classification. In addition, for each of the four categories the mean values for three performance indicators were computed: ROA, ROS and ROI. As table 4.1 shows, the simple comparison of means show that lean adopters appear to maintain on average a better performance for all of the indicators in periods of stability. Looking instead at the firms operating in periods characterized by turbulence, the difference in the means is still present, but the values suggest that it may be more moderate.

Table 4.1 – Mean of performance indicators for lean adopters and outsiders

	Lean adopters		***Outsiders***		
	Performance indicator	*Mean value*	*Performance indicator*	*Mean value*	**Difference in the means**
Periods of turbulence	ROA:	5,23	ROA:	4,87	0,36
	ROS:	3,82	ROS:	3,76	0,06
	ROI:	8,00	ROI:	6,92	1,07
Periods of stability	ROA:	7,31	ROA:	6,33	0,98
	ROS:	6,44	ROS:	6,14	0,30
	ROI:	11,20	ROI:	9,38	1,81

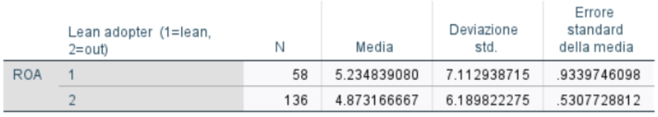
Observing the difference among the means alone is however not enough to draw valid conclusions. A further step is necessary, employing statistical testing. Specifically, the average values for each dual set of values (lean adopters against outsiders, respectively in stability and in turbulent periods) have been subjected to a t-test. The reason why a t-test analysis was chosen is that its purpose is to verify the statistical significance of the difference between two means in unrelated groups. That is to say that the test considers the following hypothesis:

- Null hypothesis *H0*: the difference in means is equal to 0
- Alternative hypothesis *H1*: the difference in mean is not equal to 0

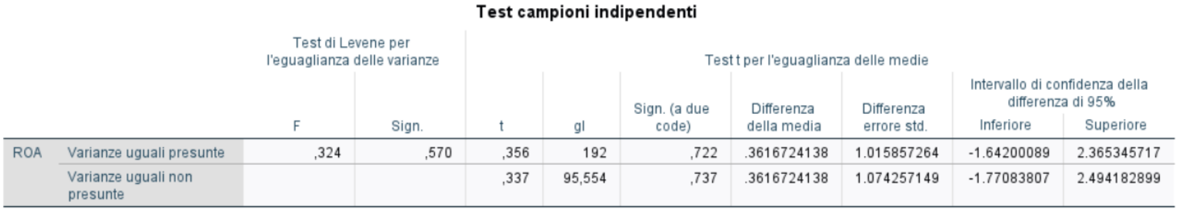
For this work, the purpose of the analysis is to see if the null hypothesis can be rejected: in fact, the objective is to understand whether the difference in the means is significant, or in other words whether there is evidence suggesting that lean adoption is impactful in creating a significantly superior (or inferior) performance. In order to determine whether the null hypothesis can be rejected, it's necessary to set a significance level, which in this case is set at 0,05. If the p-value obtained from the t-test results to be less than 0,05 (<0,05), then the null hypothesis H0 will be rejected, and the analysis will show evidence in favor of a significant difference between the means.

Specifically, the test conducted is a two-sample t-test, which compares in each iteration two independent groups, and was computed through the statistical software IBM SSPS. In order to conduct the test, the following conditions had to be respected: the two groups compared at each iteration are independent, and they have equal variances (tested through Levene's Test for the equality of variances, also computed through the IBM SSPS software). Moreover, the dependent variables (ROA, ROS, ROI) are numerical and continuous, and one categorical value is employed, with only two levels (in our case, either "lean adopter - 1" or "outsider - 2"). In the following pages, the outputs produced by the software for each t-test are displayed, in Table 4.2 for firms operating in situations of turbulence and in table 4.3 for firms in situations of stability; the results of the analysis are then summarized in table 4.4 and discussed.

Table 4.2 – T-test results for firms in conditions of turbulence

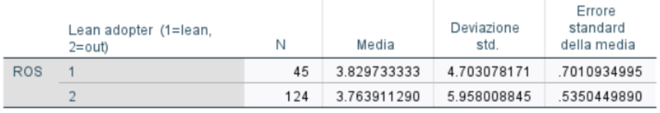


	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROA	1	58	5.234839080	7.112938715	.9339746098
	2	136	4.873166667	6.189822275	.5307728812

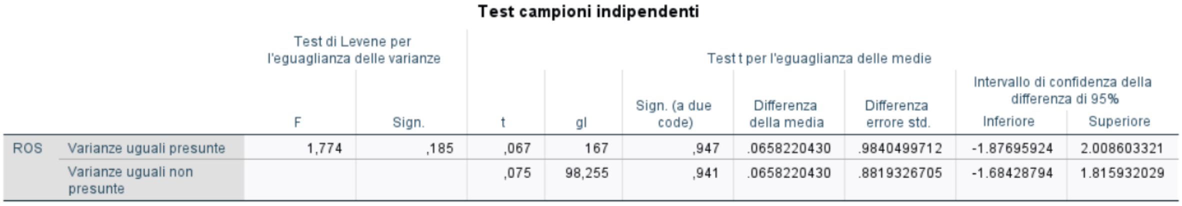


Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROA	Varianze uguali presunte	,324	,570	,356	192	,722	.3616724138	1.015857264	-1.64200089	2.365345717
	Varianze uguali non presunte			,337	95,554	,737	.3616724138	1.074257149	-1.77083807	2.494182899

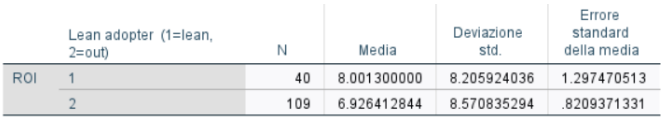


	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROS	1	45	3.829733333	4.703078171	.7010934995
	2	124	3.763911290	5.958008845	.5350449890

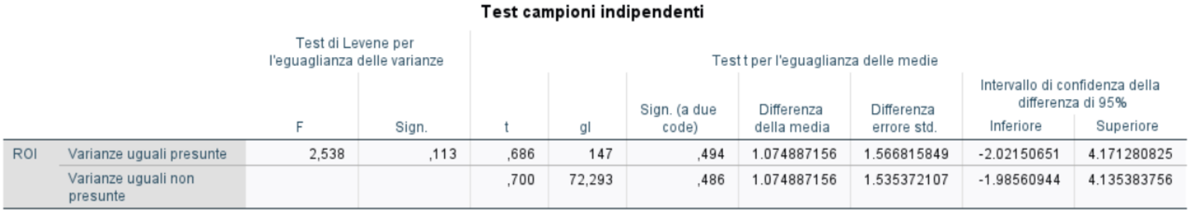


Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROS	Varianze uguali presunte	1,774	,185	,067	167	,947	.0658220430	.9840499712	-1.87695924	2.008603321
	Varianze uguali non presunte			,075	98,255	,941	.0658220430	.8819326705	-1.68428794	1.815932029



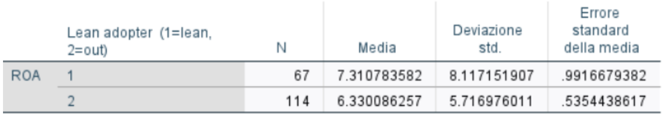
	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROI	1	40	8.001300000	8.205924036	1.297470513
	2	109	6.926412844	8.570835294	.8209371331



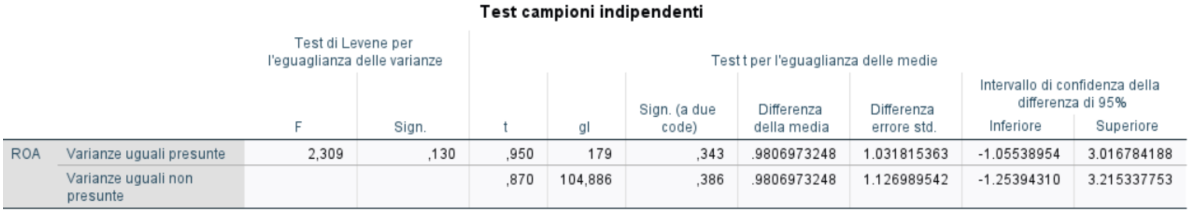
Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROI	Varianze uguali presunte	2,538	,113	,686	147	,494	1.074887156	1.566815849	-2.02150651	4.171280825
	Varianze uguali non presunte			,700	72,293	,486	1.074887156	1.535372107	-1.98560944	4.135383756

Table 4.3 – T-test results for firms in conditions of stability

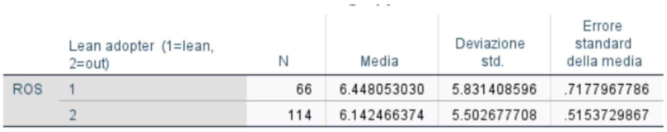


	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROA	1	67	7.310783582	8.117151907	.9916679382
	2	114	6.330086257	5.716976011	.5354438617

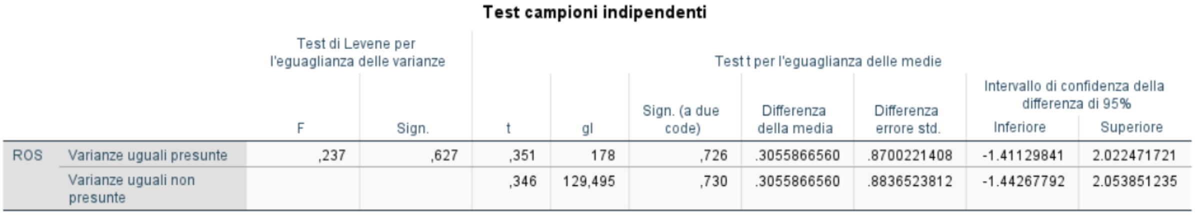


Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROA	Varianze uguali presunte	2,309	,130	,950	179	,343	.9806973248	1.031815363	-1.05538954	3.016784188
	Varianze uguali non presunte			,870	104,886	,386	.9806973248	1.126989542	-1.25394310	3.215337753

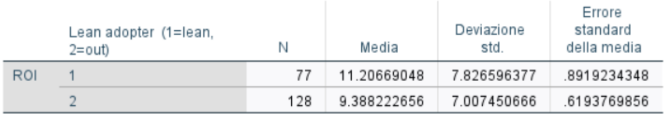


	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROS	1	66	6.448053030	5.831408596	.7177967786
	2	114	6.142466374	5.502677708	.5153729867

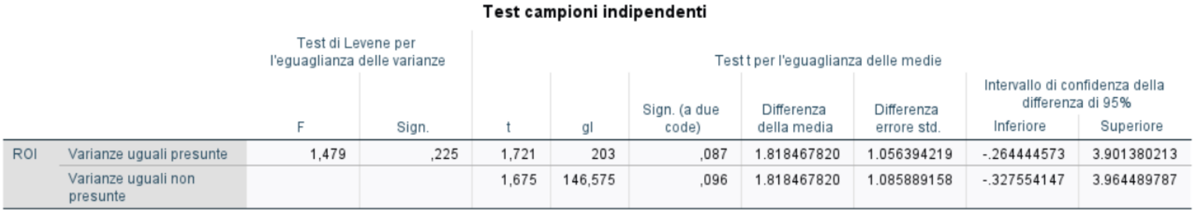


Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROS	Varianze uguali presunte	,237	,627	,351	178	,726	.3055866560	.8700221408	-1.41129841	2.022471721
	Varianze uguali non presunte			,346	129,495	,730	.3055866560	.8836523812	-1.44267792	2.053851235



	Lean adopter (1=lean, 2=out)	N	Media	Deviazione std.	Errore standard della media
ROI	1	77	11.20669048	7.826596377	.8919234348
	2	128	9.388222656	7.007450666	.6193769856



Test campioni indipendenti

		Test di Levene per l'eguaglianza delle varianze		Test t per l'eguaglianza delle medie						
									Intervallo di confidenza della differenza di 95%	
		F	Sign.	t	gl	Sign. (a due code)	Differenza della media	Differenza errore std.	Inferiore	Superiore
ROI	Varianze uguali presunte	1,479	,225	1,721	203	,087	1.818467820	1.056394219	-.264444573	3.901380213
	Varianze uguali non presunte			1,675	146,575	,096	1.818467820	1.085889158	-.327554147	3.964489787

Table 4.4 summarizes the result of the t-tests conducted. While it appears evident that in the periods of relative stability for all indicators lean firms have shown a superior performance on average, the same can't be said for the periods following disruptions, where the differences are weaker; moreover, unfortunately none of the differences in means observed appear to be significant.

In fact, the p-values show for all indicators a superior value to what would be required for it to be accepted within the confidence interval of 95%, which means that the results of these tests don't allow to refuse the null hypothesis. The reason behind this is unclear: while on the one hand it could be due to the differences in the means not being significantly different from zero, the results could also have been affected by the small sizes of the samples compared. Nonetheless, the results don't allow to draw solid conclusions in support of either a negative or a positive difference in behavior of lean firms through periods of crisis, and therefore a different approach is necessary.

Table 4.4 – Summary of the T-test analysis

	Lean adopters		***Outsiders***				
	Indicator of performance	*Mean value*	*Indicator of performance*	*Mean value*	*Mean difference*	*P-value*	*P-value <0,05*
Periods of high variability	ROA:	5,23	ROA:	4,87	0,36	0,722	**Not refuse H0**
	ROS:	3,82	ROS:	3,76	0,06	0,947	**Not refuse H0**
	ROI:	8,00	ROI:	6,92	1,07	0,494	**Not refuse H0**
Periods of low variability	ROA:	7,31	ROA:	6,33	0,98	0,343	**Not refuse H0**
	ROS:	6,44	ROS:	6,14	0,30	0,726	**Not refuse H0**
	ROI:	11,20	ROI:	9,38	1,81	0,087	**Not refuse H0**

CHAPTER 5

MULTIPLE LINEAR REGRESSION ANALYSIS

5.1 – Multiple Linear Regression analysis on performance indicators

The T-test analysis conducted in the previous chapter showed positive differences in the means between lean adopters and non-adopters, seemingly suggesting that a positive impact of lean adoption on performance exists, in relatively stable business conditions but as well in situations where firms have to face disruptions and turbulence. However, the results were not statistically significant, and therefore don't allow to draw valid conclusions. For this reason, in the following chapter a different, more focused analysis is attempted.

This second analysis is conducted employing multiple linear regressions, a type of statistical analysis whose purpose is to understand whether the variation in a dependent variable is due to the variations in a series of independent variables, and specifically to what extent. The parameters for the multiple regression were estimated through an OLS Regression, a method that selects the parameters of the independent variables by minimizing the sum of the squared differences between the values of the dependent variable observed in the dataset and those predicted through the linear function. The data available, gathered from the survey and from the AIDA database, was employed to define the dependent and independent variables.

Starting from the dependent variables, the same measures of financial performance on which the t-test were conducted in the previous chapter were selected: ROA, ROS and ROI were each employed as a dependent variable in a different multiple regression. In particular, the dependent variables were considered as the 5-year mean of the values of each indicator between the years 2014 and 2018, for each company. As before, these indicators are employed to evaluate financial performance, under the assumption that resilience can be assessed as a higher level of financial performance in a selected time period.

To conduct the analysis, independent variables were also defined. For the purpose of this analysis, three explanatory variables were particularly relevant:

- The "*Lean*" variable was introduced to distinguish between lean companies and outsiders. It is a binary variable, that assumes the value "1" for Lean companies and "0" for outsiders. As will be clarified, for this analysis firms that became lean adopters after the year 2014 were excluded.

- The *"Coefficient of Variation*" variables were employed to describe the level of turbulence in business performance experienced by a company in a specified period of time. They are continuous variables, computed as the absolute ratio between the Standard Deviation of the values assumed by each indicator (ROA, ROS and ROI) in the 2014-18 period and the Mean of the values of the same indicator in the 5-year period. The same indicators were employed in chapter 3 to evaluate the level of turbulence in different industries, but for the purpose of this second analysis they were computed at firm level, to capture the individual level of turbulence experienced by each firm in the time period considered.
- The *"Lean x Coefficient of variation"* terms were introduced to account for the joint presence of lean adoption and of a certain level of turbulence, and in particular to evaluate whether the effect of lean adoption variates relatively to increasing levels of variability in performance. They are interaction terms, computed as the product between the values assumed by the binary "*Lean*" variable and of the values assumed by the continuous *"Coefficient of variation"* variable.

In addition, some further explanatory variables were added, to control for the impact of other factors that could influence the financial performance[8]. The following were employed:

- The "*Size*" variable, a continuous variable computed as the average number of employees in the 5-year period, representing the dimension of the firms.
- The *"Past performance"* variable, a continuous variable computed as the mean of the values for each respective indicator (ROA, ROS and ROI) in the 5-year period (2009-2013) preceding the period considered to define the dependent variable.
- The "*Industry*" variables, introduced as a series of dummy variables representing the membership of each company to one of the 6 industries considered. Specifically, five dummy variables were employed: "*ATECO 10*", "*ATECO 20*", "*ATECO 24*", "*ATECO 27*" and "*ATECO 28*".

It's important to mention that the number of firms present in the original sample was not considered in its entirety. Specifically, while the analysis in chapter 3 focused on a sample of 344 firms, an adjustment was made in relation to lean companies: companies that became lean adopters after the year 2014 were excluded, to avoid including in the 2014-18 mean companies that hadn't been implementing the practices over the entire period, and thus avoid misleading results. This led to a sample of 263 firms, which was also the basis for the t-test

---

[8] A summary of the descriptive statistics for the variables employed in all the regressions is available in Appendix 2

analysis in chapter 4. Finally, to avoid the influence of possible outliers, the remaining database was adjusted to remove the 10% of extreme data for each indicator of financial performance. This led to a final sample of 237 firms on which the analysis was based; within this sample, 92 firms were lean adopters and 145 were outsiders.

The analysis was carried out through the IBM SPSS software. In the next pages the outputs resulting from the analysis are summarized and discussed. Specifically, a first regression was carried out by including only the "*Lean*" independent variable, to which the control which the control variables *"Size"*, *"Past performance*" and "*Industry*" were added. This first model is employed to observe the general impact of lean adoption on the indicators of performance, which is a necessary step given the unclear results that emerged from the t-test analysis. The model tested is therefore the following:

Model 1:

$$Y = \beta_0 + \beta_1 Lean + \beta_2 Size + \beta_3 Past\ Performance + \beta_4 Industry + \varepsilon$$

Table 5.1 Summary of the regression model results – Model 1[9]

	ROA	***ROS***	***ROI***
Constant	6,736 *** (1,750)	6,203 ** (1,436)	12,122 *** (2,667)
Lean	1,283 ** (0,612)	0,745 (0,535)	1,620 * (0,956)
Size	-1,114 * (0,663)	-0,763 (0,578)	-1,785 * (1,036)
Past Performance	0,412 *** (0,049)	0,413 *** (0,051)	0,424 *** (0,055)
Industry: ATECO 10	-0,841 (1,465)	-0,931 (1,184)	-3,710 * (2,136)
Industry: ATECO 20	-1,775 (1,388)	-1,900 * (1,106)	-3,457 * (2,052)
Industry: ATECO 24	-0,907 (1,275)	-1,007 (1,015)	-2,378 (1,846)
Industry: ATECO 27	-0,510 (1,409)	-1,429 (1,134)	-1,520 (2,086)
Industry: ATECO 28	-0.491 (1,254)	-0,422 (0,997)	-0,759 (1,820)
Observations	228	227	221
R^2	0,276	0,268	0,273
Adj R^2	0,249	0,241	0,246

---

[9] "*" p-value < 0,1
"**" p-value < 0,05
"***" p-value < 0,01

Table 5.1 summarizes the estimated coefficients for the regressions conducted, and a first observation can be made regarding the Adjusted R^2 for the regressions. The Adjusted R^2 is a measure of goodness of fit, that ranges from 0 to 1, and describes how much of the variability in the dependent variables can be explained by the variability in the independent variables employed in the model (Hanke & Wichern, 2009). In the case of these regressions, the Adj R^2 ranges from 0,241 to 0,249, suggesting that while some of the variability can be explained by the variables considered, there are also other factors impacting the performance of the firms that were not included in the model. However some further considerations about the individual results observed can still be made.

The regressions provided estimates of the coefficients for each independent variable, and these estimates capture the average change in the dependent variable caused by a unit change in each independent variable, in terms of intensity and direction, keeping the other variables constant. An important observation to be made is that not all estimates reach a significant level, based on their p-values. In particular, the "*Industry*" variables, included to represent the membership to a particular industry, have negative estimates of the coefficients in all cases, but these estimates don't appear to be significant. Instead, other control variables appear to be significant: the "*Size*" variable, included to represent the dimension of a firm in terms of its employees, shows negative estimates significant at 10% for ROA and ROI, suggesting a negative impact on performance caused by increasing dimensions. The *"Past performance*" variable reaches a significant level at 1% in each of the five regressions, suggesting with the positive value of its estimated coefficients that the past performance of a firm definitely has a role in explaining its current performance.

The real purpose of Model 1 was to assess the impact of lean adoption. Looking therefore at the "*Lean*" variable, we find that the estimated coefficients are all positive, which seems to confirm the hypothesis that all other factors being constant, the adoption of lean leads to a better financial performance. In particular, the estimates reach a significant level for ROA at 5% and for ROI at 10%.

Having observed the effect of lean adoption, a second set of regressions was conducted, adding in this second model the independent variables *"Coefficient of variation"*, aimed at capturing the level of turbulence that affected a firm during the time period considered. This second model therefore wants to test both the impact of lean adoption and the impact of a turbulent period on the performance of firms, although considering the two effects independently from one another, and it's necessary to assess whether a higher level of variability in business performance is indeed associated to a worse average performance, as was hypothesized. The model is specified as follows:

Model 2:

$$Y = \beta_0 + \beta_1 Lean + \beta_2 Coefficient\ of\ variation + \beta_3 Size + \beta_4 Past\ Performance + \beta_5 Industry + \varepsilon$$

Table 5.2 - Summary of the regression model results – Model 2

	ROA	***ROS***	***ROI***
Constant	8,138 *** (1,643)	6,466 ** (1,421)	12,303 *** (2,633)
Lean	1,741 *** (0,574)	0,929 * (0,533)	1,751 * (0,919)
Coefficient of Variation	-0,478 *** (0,080)	-0,023 ** (0,009)	-0,587 *** (0,127)
Size	-1,501 ** (0,016)	-0,918 (0,574)	-1,601 (1,010)
Past Performance	0,367 *** (0,046)	0,412 *** (0,051)	0,359 *** (0,055)
Industry: ATECO 10	-1,180 (1,363)	-0,951 (1,169)	-2,772 (2,096)
Industry: ATECO 20	-1,799 (1,290)	-1,933 * (1,092)	-2,801 (2,007)
Industry: ATECO 24	-0,865 (1,185)	-0,893 (1,003)	-2,162 (1,822)
Industry: ATECO 27	-0,671 (1,310)	-1,411 (1,119)	-0,213 (2,042)
Industry: ATECO 28	-0,598 (1,166)	-0,449 (0,984)	-0,405 (1,790)
Observations	228	227	214
R^2	0,377	0,290	0,323
Adj R^2	0,351	0,261	0,294

Table 5.2 summarizes the estimated coefficients for the regression. In this second set of regressions the Adj R^2 goes from 0,261 to 0,351, suggesting again that while some of the variability is explained by the variables considered, there are other relevant factors that were not included in the model. As for the estimated coefficients, similar considerations can be made to what was observed previously. Not all of the estimated coefficients reach a significant level, based on their p-values, and specifically the "*Industry*" variables and the "*Size*" variable show again mostly negative estimates of the coefficients, but that don't appear to be significant, with the exception of the *Size* variable in the regression for ROA. Instead, the *"Past performance*" variable reaches in this second model as well a significant level at 1% in each of the five regressions. Considering the estimated coefficients for the "*Lean*" variable, the regressions show again a positive relationship between lean adoption and performance,

with positive estimates of the coefficients, with a significant level for ROA (at 5%), ROS and ROI (at 10%).

The relevant explanatory variable on which to focus is however the *"Coefficient of Variation*", chosen to identify the level of turbulence experienced by each firm over the 5-year period considered. In this case, the estimates are significant for all indicators, and moreover they all have a negative sign, suggesting, as was hypothesized, that a higher level of turbulence in a certain time period negatively impacts the average performance of a firm.

After these necessary preliminary considerations, a third set of regressions was conducted, adding in this iteration the interaction terms *"Lean x Coefficient of Variation"*. The decision to adopt an interaction term was aimed at understanding the combined effect on the performance indicators of a company being a lean adopter and experiencing a period of turbulence at the same time. Therefore, the objective is to understand whether there is evidence that lean adoption may moderate, or on the opposite enhance, the negative impact of high variability in a certain period. The model is specified as follows:

Model 3:

$$Y = \beta_0 + \beta_1 Lean + \beta_2 Coefficient\ of\ variation + \beta_3 Lean\ x\ Coefficient\ of\ variation + \beta_4 Size + \beta_5 Past\ Performance + \beta_6 Industry + \varepsilon$$

Table 5.3 summarizes the estimated coefficients for the regressions conducted. In this set of regressions, the Adj R^2 ranges from 0.295 to 0.358, improving from the previous models. Regarding instead the estimates for the "*Size*", "*Industry*", and "*Past performance*" variables, they all present values, direction and significance in line with what was observed for the previous models, so they won't be commented further.

Considering the *"Coefficient of Variation*" variable, it shows significant estimates with a negative sign for all indicators. Instead for the "*Lean*" variable the regressions show positive estimates of the coefficients, although in this case again they only reach a significant level for ROA (at 5%). However, differently from the previous models, this model includes a third explanatory variable, the interaction term *"Lean x Coefficient of Variation"*. Since an interaction term is included, in situations in which the main variables *"Lean"* and of "*Coefficient of variation*" assume values different from zero the effects of their estimated coefficients can't be interpreted as unconditional effects (Brambor et al., 2006); what must be interpreted is the total effect, which will consider jointly the coefficients of the main variable and the interaction term. Thus, the marginal effect associated to the *"lean"* variable will be equal to $(\beta_1 + \beta_3 * Coefficient\ of\ variation)$, while the marginal effect associated to the *"coefficient of variation"* variable will be equal to $(\beta_2 + \beta_3 * Lean)$; since the *"lean"* variable is a binary that can only assume the values 0 or 1, this second effect will be equal to β_2 in outsider firms and to $(\beta_2 + \beta_3)$ in lean firms.

Specifically, in these regressions the interaction term shows positive estimates for all three indicators, significant at 10% for ROA and at 1% for ROS and ROI. This significance of the interaction term estimates seems to suggest two observations: first, that effect of lean adoption on the dependent variables is not constant, but influenced by the level of variability; and since both coefficients have positive signs, the effect of lean adoption on performance doesn't appear to be impaired by increasing turbulence. And second, since the estimates of the interaction term have a positive sign, in contrast with the negative sign assumed by the estimates of "*coefficient of variation"*, it appears that the adoption of lean may moderate the negative effect of a high variability in a certain period. To provide a clearer explanation, Table 5.4 shows the net effects of the explanatory variables, accounting for the comprehensive effects of the main and the interaction term.

Table 5.3 Summary of the regression model results – Model 3

	ROA	***ROS***	***ROI***
Constant	8,553 ***	7,133 ***	13,842 ***
	(1,651)	(1,401)	(2,648)
Lean	1,333 **	0,494	0,987
	(0,614)	(0,535)	(0,945)
Coefficient of Variation	-0,763 ***	-0,418 ***	-1,309 ***
	(0,177)	(0,115)	(0,287)
*Lean **x** Coefficient of Variation*	0,357 *	0,397 ***	0,888 ***
	(0,197)	(0,116)	(0,317)
Size	-1,569 **	-1,027 *	-2,014 *
	(0,618)	(0,561)	(1,004)
Past Performance	0,358 ***	0,375 ***	0,343 ***
	(0,046)	(0,050)	(0,055)
Industry: ATECO 10	-1,249	-1,022	-3,012
	(1,357)	(1,141)	(2,063)
Industry: ATECO 20	-1,552	-1,549	-2,427
	(1,291)	(1,072)	(1,979)
Industry: ATECO 24	-0,923	-0,834	-2,325
	(1,180)	(0,980)	(1,793)
Industry: ATECO 27	-0,499	-1,167	-0,250
	(1,307)	(1,095)	(2,008)
Industry: ATECO 28	-0.539	-0,330	-0,372
	(1,160)	(0,962)	(1,761)
Observations	228	227	214
R^2	0,386	0,326	0,348
Adj R^2	0,358	0,295	0,316

Table 5.4 – Net effect of explanatory variables in Model 3

	ROA	*ROS*	*ROI*
Marginal effect of "Lean" (Lean=1)	1,333 + 0,357 * CV	0,494 + 0,397 * CV	0,987 + 0,888 *CV
Marginal effect of CV – Lean (Lean=1)	-0,406	- 0,021	-0,421
Marginal effect of CV – Outsider (Lean=0)	-0,763	- 0,418	- 1,309

5.2 – Multiple Linear Regression analysis: the maturity of lean adoption

While the results of the regression in model 3 seem to support the hypothesis of a positive association between lean adoption and financial performance, even accounting for increasing levels of turbulence, it's worth to attempt additional analysis to assess the robustness of these results. For a deeper analysis, an aspect that could be considered is that the sample firms show heterogeneity regarding their experience with lean. In fact, while the sample excludes lean implementers after 2014, the remaining firms still show heterogeneity regarding their lean maturity, which is the number of years for which a company has been implementing lean, as was observed in Chapter 3 (Graph 3.39). The maturity of implementation is a relevant factor: as was discussed in Chapter 1, traditional accounting system may not reflect immediately the operational improvements associated to lean transformations; as a consequence, firms who have been implementing lean for a limited number of years may not see results on their financial performance.

Therefore, additional regressions were conducted, considering as a criteria to evaluate lean maturity the number of years for which each company has been implementing at least one lean management practice. The purpose of this further analysis is test if firms with different levels of maturity behave differently (Model 4), particularly in relation to the level of variability in the period (Model 5). Lean firms were divided in two classes: a firm was considered an experienced adopter if it had been implementing lean for at least 2 years (computed as of 2014, since lean adopters after the year 2014 were excluded from the sample), otherwise it was considered a recent adopter. Following this criteria, the sample showed the following composition: 19 recent adopters (20% of lean firms) and 73 experienced adopters (80% of lean firms), compared as in the previous models to145 outsiders.

In the new model, the following adjustments to the dependent variables had to be introduced:

- The independent binary variable "*Lean*" was removed and replaced by two independent binary variables: *"Lean: experienced",* which assumes the value of 1 if a firm is lean experienced and 0 otherwise; and "*Lean: recent"* which assumes the value of 1 if a firm is a lean recent and 0 otherwise.
- The independent variable *"Lean x coefficient of interaction"* was also removed and replaced by two distinct independent variables: *"Lean experienced x Coefficient of variation*" and *"Lean recent x Coefficient of variation"*.

First, a series of regressions were conducted without the interaction term, to assess if a longer period of lean implementation, and the experience gained throughout those years, have an influence on the company's performance. The resulting model is the following:

Model 4:

$$Y = \beta_0 + \beta_1 Lean\ experienced + \beta_2 Lean\ recent + \beta_3 Size + \beta_4 Past\ Performance + \beta_5 Industry + \varepsilon$$

The results in Table 5.5 show that the estimates associated to the "*lean experienced*" variable are positive and significant for two indicators (5% for ROA, 10% for ROI), while the for the "*lean recent*" variable the coefficients appear positive but not significant, suggesting that the effect on financial performance may only be visible after a few years of implementation.

Table 5.5 Summary of the regression model results – Model 4

	ROA	***ROS***	***ROI***
Constant	6,803 *** (1,759)	6,219 *** (1,446)	12,217 *** (2,687)
Lean: experienced	1,393 ** (0,659)	0,769 (0,578)	1,742 * (1,023)
Lean: recent	0,923 (1,002)	0,668 (0,864)	1,182 (1,593)
Size	-1,150 * (0,669)	-0,770 (0,583)	-1,816 * (1,042)
Past Performance	0,412 *** (0,049)	0,413 *** (0,051)	0,425 *** (0,055)
Industry: ATECO 10	-0,866 (1,469)	-0,942 (1,191)	-3,780 * (2,150)
Industry: ATECO 20	-1,782 (1,391)	-1,903 * (1,109)	-3,497 * (2,060)
Industry: ATECO 24	-0,914 (1,277)	-1,012 (1,019)	-2,425 (1,855)
Industry: ATECO 27	-0,524 (1,412)	-1,437 (1,139)	-1,571 (2,095)
Industry: ATECO 28	-0,494 (1,256)	-0,428 (1,001)	-0,804 (1,829)
Observations	228	227	221
R^2	0,276	0,268	0,274
Adj R^2	0,247	0,238	0,243

Having observed the individual effects of different classes of maturity, a second set of regressions was conducted including the interaction term. Results are shown in Table 5.6.

Model 5:

$$\begin{gathered}Y = \beta_0 + \beta_1 Lean\ experienced + \beta_3\ Lean\ recent + \beta_4\ Coefficient\ of\ variation + \\ \beta_4 Lean\ experienced\ x\ Coefficient\ of\ variation + \beta_5 Lean\ recent\ x\ Coefficient\ of\ variation + \beta_6 Size + \\ \beta_7 Past\ Performance + \beta_8 Industry + \varepsilon\end{gathered}$$

Table 5.6 Summary of the regression model results – Model 5

	ROA	***ROS***	***ROI***
Constant	8,583 *** (1,659)	6,952 *** (1,396)	13,953 *** (2,663)
Lean: Experienced	1,429 ** (0,654)	0,625 (0,573)	1,162 (0,994)
Lean: Recent	1,080 (1,019)	0,655 (0,857)	0,304 (1,698)
Coefficient of Variation	-0,765 *** (0,177)	-0,421 *** (0,114)	-1,312 *** (0,288)
Lean experienced ***x*** *Coefficient of Variation*	0,257 (0,217)	0,236 * (0,134)	0,911 ** (0,325)
Lean recent ***x*** *Coefficient of Variation*	0,459 ** (0,218)	0,402 *** (0,115)	0,831 * (0,428)
Size	-1,553 ** (0,622)	-0,907 (0,561)	-2,058 ** (1,010)
Past Performance	0,356 *** (0,046)	0,366 *** (0,050)	0,342 *** (0,055)
Industry: ATECO 10	-1,307 (1,361)	-0,948 (1,136)	-3,076 (2,074)
Industry: ATECO 20	-1,597 (1,294)	-1,574 (1,064)	-2,442 (1,987)
Industry: ATECO 24	-1,011 (1,184)	-0,872 (0,973)	-2,334 (1,802)
Industry: ATECO 27	-0,557 (1,310)	-0,934 (1,092)	-0,316 (2,020)
Industry: ATECO 28	-0,541 (1,162)	-0,347 (0,955)	-0,410 (1,769)
Observations	228	227	214
R^2	0,390	0,343	0,350
Adj R^2	0,356	0,306	0,311

In these regressions, the *"coefficient of variation"* confirms the direction of their estimates and reach significant levels for all three indicators, while for lean adoption the only variable that appears significant is *"lean experienced"* for ROA. As for the interaction term, the results show that its estimates reach a positive and significant level in all cases except for the *"Lean experienced"* in ROA. Interpreting as before the joint effect of the main term and of the interaction term, this result thus appears to provide further confirmation that lean adoption may have a moderating effect on the negative impact of increasing variability, strengthening the results observed for Model 3. At the same time, there doesn’t seem to be any evidence to account for a difference in behavior between recent and mature lean adopters. To provide more clarity, table 5.7 shows the total effect of the explanatory variables, accounting for the interaction term.

Table 5.7 – Net effect of explanatory variables in Model 5

	ROA	***ROS***	***ROI***
Marginal effect of “Lean experienced” (Lean experienced=1)	1,429 + 0,257 * CV	0,625 + 0,236 * CV	1,162 + 0,911 *CV
Marginal effect of “Lean recent” (Lean beginner=1)	1,080 + 0,459 * CV	0,655 + 0,402 * CV	0,304 + 0,381 * CV
Marginal effect of CV – Lean experienced (Lean experienced =1)	-0,508	- 0,185	-0,401
Marginal effect of CV – Lean recent (Lean recent =1)	-0,306	- 0,019	-0,481
Marginal effect of CV – Outsider (L-experienced=0; L-recent=0)	-0,765	- 0,421	- 1,312

5.3 – Multiple Linear Regression analysis: the extent of lean adoption

The distinction of firms based on their years of experience with lean didn’t provide evidence in support of a different behavior. A different perspective that could be adopted is focusing on the fact that lean firms don’t all adopt lean management to the same extent; in fact, the criteria that was employed to consider a firm “lean” was the adoption of at least one lean practice, but looking at the sample the range of lean practices in the firms goes from 1 to 57 practices, with a median value of 11 practices (see Graph 3.36). In addition, some insights from the literature review seemed to suggest that only an extensive lean implementation, that goes beyond a restricted number of production-focused lean practices, could represent an asset for firm resilience (Azadegan et al., 2013; Birkie, 2016), raising the question of whether different extents of lean adoption could have different impacts on performance.

Therefore, additional regressions were conducted with a different segmentation, considering as a criteria not the number of years of implementation but rather the number of practices implemented by each firm. For symmetry with the previous Model 4 and 5, lean firms were divided into two categories: the 20% of firms implementing the least practices were considered as lean beginners, while the remaining 80% of firms were considered as advanced adopters. Applying this criteria, the cut-off was set at 7 lean practices, obtaining a sample with the following composition: 73 advanced firms, 19 beginners, and once again 145 outsiders. Specifically, this segmentation allows to evaluate whether a limited lean implementation is related to difference in behavior.

In the new model, the following adjustments to the dependent variables had to be introduced:

- The independent binary variable "*Lean*" was replaced by two independent binary variables: *"Lean: advanced",* which assumes the value of 1 if a firm is lean advanced and 0 otherwise; and "*Lean: beginners"* which assumes the value of 1 if a firm is a lean beginner and 0 otherwise.
- The independent variable *"Lean x coefficient of interaction"* was also removed and replaced by two distinct independent variables: *"Lean Advanced x Coefficient of variation*" and *"Lean Beginner x Coefficient of variation"*.

A preliminary regression was conducted to evaluate only the effect of lean adoption, divided in this case among "*lean beginners*" and "*lean advanced"*. The resulting model is the following, and results of the regressions are shown and discussed in Table 5.8.

Model 6:

$$Y = \beta_0 + \beta_1 Lean{:}Advanced + \beta_2 Lean{:}Beginner + \beta_3 Size + \beta_4 Past\ Performance + \beta_5 Industry + \varepsilon$$

Table 5.8 - Summary of the regression model results – Model 6

	ROA	***ROS***	***ROI***
Constant	6,554 *** (1,757)	5,987 *** (1,438)	12,279 *** (2,693)
Lean: advanced	0,965 (0,681)	0,360 (0,588)	1,845 * (1,070)
Lean: beginner	2,076 ** (0,965)	1,804 ** (0,866)	1,079 (1,493)
Size	-0,954 (0,680)	-0,564 (0,591)	-1,905 * (1,068)
Past Performance	0,409 *** (0,049)	0,406 *** (0,051)	0,425 *** (0,055)
Industry: ATECO 10	-0,964 (1,469)	-1,065 (1,184)	-3,648 * (2,144)
Industry: ATECO 20	-1,757 (1,388)	-1,883 * (1,103)	-3,483 * (2,056)
Industry: ATECO 24	-1,001 (1,278)	-1,131 (1,015)	-2,316 (1,854)
Industry: ATECO 27	-0,603 (1,411)	-1,553 (1,133)	-1,462 (2,093)
Industry: ATECO 28	-0,551 (1,255)	-0,521 (0,996)	-0,726 (1,825)

Observations	228	227	221
R^2	0,279	0,276	0,274
Adj R^2	0,250	0,246	0,243

The results show that the estimated coefficients for “*Lean: Advanced*” and “*Lean: Beginners*” are always positive, suggesting again the hypothesis of a positive relation between lean adoption and performance. However, they are only significant for “*Lean Beginners*” in the case of ROA and ROS (5%) and for *“Lean Advanced”* for ROI (10%), so it isn’t possible to evaluate clearly whether a distinction between the two categories is present.

A second regression was conducted, adding in this case the “*coefficient of variation”* variable and the two interaction terms described above. The model is specified as follows and results are presented in Table 5.9.

Model 7:

$$Y = \beta_0 + \beta_1 Lean{:} Advanced + \beta_2 Lean{:} Beginner + \beta_3 Coefficient\ of\ variation + \\ \beta_4 Lean{:} Advanced\ x\ Coefficient\ of\ variation + \beta_5 Lean{:} Beginner\ x\ Coefficient\ of\ variation + \\ \beta_6 Size + \beta_7 Past\ Performance + \beta_8 Industry + \varepsilon$$

In this set of regressions, the estimated coefficients for “*Lean: Advanced*” and “*Lean: Beginners*” are always positive, and significant for “*Lean Beginners*” in the case of ROA, ROS (1%) and ROI (10%), while those for *“Coefficient of variation*” are always negative and significant. However, as was observed for Model 3, the estimates need to be evaluated relatively to the interaction term. Differently from Model 6, the results of this additional model seem to show a difference among beginners and advanced firms.

As before, the comprehensive effect of lean adoption on performance needs to consider both the effect of the main variable “*Lean beginner”* and the effect of its relative interaction term. However in this case the estimates of their coefficients have opposite direction: the estimates for the interaction term “*Lean beginners x Coefficient of variation*” are in fact significant and negative in each of the three regression. Therefore the comprehensive effect of lean adoption will depend on the level of variability: while in a context of low level variability the positive impact of lean on performance may prevail, this positive impact is negatively moderated by an increasing level of turbulence in the time period, and for high levels of variability the negative effect will prevail.

On the other hand, different results are found for the "*Lean advanced x Coefficient of variation*" estimates: they are positive and significant for ROA, ROS and ROI, just as was observed for the general case in model 3, and so they can be interpreted as before. Table 5.10 displays the net effect of the explanatory variables, accounting for the comprehensive effects of the main and the interaction term.

In conclusion, while the results for *"lean advanced"* provide confirmation on the moderating effect of turbulence obtained through lean implementation, the results for "*lean beginner*" contradict it. It could be thus argued that differently from the level of maturity, the extent of implementation has a different impact on the effect of lean adoption; in fact, the results show that the moderating effect can only be observed in firms that reach a minimum threshold of lean practices simultaneously adopted.

Table 5.9 - Summary of the regression model results – Model 7

	ROA	***ROS***	***ROI***
Constant	8,375 ***	6,895 ***	14,147 ***
	(1,637)	(1,376)	(2,630)
Lean: Advanced (B)	1,095	0,111	1,320
	(0,676)	(0,578)	(1,031)
Lean: Beginners (B)	3,636 ***	3,485 ***	2,994 *
	(1,132)	(1,053)	(1,763)
Coefficient of Variation	-0,773 ***	-0,431 ***	-1,324 ***
	(0,174)	(0,113)	(0,282)
Lean advanced ***x*** *Coefficient of Variation*	0,393 **	0,411 ***	0,930 ***
	(0,195)	(0,113)	(0,312)
Lean beginners ***x*** *Coefficient of Variation*	-2,631 **	-2,843 ***	-3,224 **
	(1,081)	(1,037)	(1,492)
Size	-1,419 *	-0,790	-2,193 *
	(0,626)	(0,563)	(1,015)
Past Performance	0,351 ***	0,358 ***	0,340 ***
	(0,045)	(0,050)	(0,054)
Industry: ATECO 10	-1,401	-1,246	-3,108
	(1,342)	(1,119)	(2,035)
Industry: ATECO 20	-1,374	-1,392	-2,258
	(1,274)	(1,049)	(1,951)
Industry: ATECO 24	-0,917	-0,880	-2,139
	(1,166)	(0,961)	(1,767)
Industry: ATECO 27	-0,558	-1,290	-0,311
	(1,290)	(1,073)	(1,979)
Industry: ATECO 28	-0,652	-0,518	-0,495
	(1,146)	(0,942)	(1,734)
Observations	228	227	214
R^2	0,409	0,362	0,375
Adj R^2	0,376	0,327	0,338

Table 5.10 – Total effect of explanatory variables in Model 7

	ROA	***ROS***	***ROI***
Marginal effect of "Lean advanced" (Lean advanced=1)	1,095 + 0,393 * CV	0,111 + 0,411 * CV	1,320 + 0,930 *CV
Marginal effect of "Lean beginner" (Lean beginner=1)	3,636 - 2,631 * CV	3,485 – 2,843 * CV	2,994 – 3,224 * CV
Marginal effect of CV – Lean Advanced (Lean advanced =1)	-0,380	-0,020	-0,394
Marginal effect of CV – Lean beginner (Lean beginner =1)	-3,404	-3,274	-4,548
Marginal effect of CV – Outsider (L-dvanced=0; L-beginner=0)	-0,773	- 0,431	-1,324

CONCLUSIONS

The increasing diffusion of lean management in the last twenty years raised interest in literature, which prompted several authors to investigate the consequences of lean adoption and its potential impact in terms of performance improvement. And while these previous contributions often provided support to the existence of a positive relationship, both in relation to operational and financial performance, a limitation of these studies was the limited attention that had been granted to understanding whether contextual factors, such as the level of turbulence in which a firm operates, affected the validity of the findings.

As the literature review proposed in Chapter 2 highlighted, there are valid arguments supporting the idea that lean may be a system better suited to stable industries and environments: its focus on the elimination of redundancies in pursuit of better efficiency appears to make operations more vulnerable to sudden changes, and consequently less resilient. Then again, the opposite thesis also finds support, with arguments claiming that the increased flexibility and the improved communications with supply chain partners observed in lean firms may constitute sources of resilience. These ambiguous insights derived from the literature debate, paired with the knowledge that facing an increasing variability in demand, supply and market dynamics represents one of the main challenges for firms today, suggested the necessity for research on the topic.

The present work therefore aimed at inserting itself in the line of literature investigating the lean-performance relation, by presenting a contribution with a specific focus on the possible linkage among lean adoption and firm resilience. Recognizing the difficulties in properly capturing resilience through financial indicators, two different approaches of analysis were employed, respectively in Chapters 4 and 5.

Discussion of the results

The first necessary step was to assess if the widespread literature results retained validity on the sample available. While some graphical comparison (Graph 3.7b to Graph 3.13b) provided evidence of a superior performance of lean firms, a more formal analysis was conducted in Chapter 4 by carrying out t-tests. In this case the focus was put on potential disruptions at industry level, and employing an indicator of performance variability, a distinction was made between industries operating in situations of relative turbulence and industries operating in situations of relative stability. Three indicators of financial performance were adopted, ROA, ROS and ROI, to compare lean adopters against non-adopters. However, the results didn't provide evidence of significant differences among the two groups in either context, prompting to adopt a different approach.

The main analysis was therefore conducted in Chapter 5, employing multiple linear regressions. This second analysis presented a more focused point of view: while accounting for industry membership through the use of sector binary variables, it considered the turbulence experienced at the single firm level. Differently from the previous analysis, the results of the regressions allowed to make meaningful considerations.

First, it provided empirical evidence in favor of a positive relation between lean adoption and performance (Model 1), supporting the hypothesis that lean implementation may produce efficiency gains in operations, which are reflected on financial performance. While some ambiguity remains (for example, Model 1 and 4 find significant coefficients for ROA and ROI, but not for ROS), the results appear nonetheless in line with previous literature findings.

However these results, while meaningful, only represent a preliminary step. The true purpose of this study was to evaluate whether the impact of lean adoption on financial performance may be moderated by different levels of business performance variability. Adopting regression models that include interaction terms, the results provided the following insights: while the increasing variability in business performance in a period of time is always associated with a worse average performance (Model 2), the results observed for ROA, ROS and ROI suggest that the positive effect on performance associated to lean adoption is maintained despite the increasing variability (Model 3). In different terms, all firms report a worse average performance during periods of time characterized by instability in business performance; however lean adopters seem to be affected to a lesser extent, providing support to the hypothesis that lean adoption positively moderates the negative impact of turbulence.

In light of the literature debate, and considering the contrasting insights provided by previous literature (Azadegan et al., 2013; Eroglu and Hofer, 2014), additional analysis were conducted to assess the robustness of the results. In particular, the purpose was to observe if different extents of lean adoption affected the results. The first distinction, based on the number of years of lean implementation, divided lean firms among recent and experienced lean adopters. However the result didn't provide evidence of a different behavior of the two groups. Overall, the years of implementation don't seem to affect firm's performance nor their resilience; yet, the results in Model 5 are still relevant, as they provide further support to the results observed in Model 3.

The final analysis (Model 6 and 7) instead assessed the experience with lean considering as a criteria the number of practices adopted. The distinction among beginners, lean firms adopting a limited number of practices, and advanced lean firms provided different results than those observed by assessing the maturity of implementation. In fact, in the final set of regressions the moderating effect of lean was observed only in advanced firms (Model 7) and not in beginner firms, suggesting that in situations of increasing turbulence a limited and fragmented lean implementation doesn't allow to obtain benefits.

Several hypothesis can be made to explain this different behavior. A consideration is that while advanced implementers adopt lean practices in several areas of the firm simultaneously, in lean beginners they appear to be limited to the production and inventory management areas (Graph 3.37). And as it was argued in literature, lean implementation limited to production may create struggles in unstable environments, as it becomes more difficult to synchronize the production with the changing supply or demand. An explanation could also lie in the type of practices implemented (Graph 3.38). Beginners appear focused on Value Stream Mapping and 5S, which are important stepping stones in lean transformations, but that, as was described in Chapter 1, are not sufficient on their own to provide lasting improvements. In addition, they appear to implement Pull and Flow techniques, which represent sources of efficiency gains, for example trough the reduction of overproduction waste, but that are also generally associated to inventory reduction; and as it was observed, inventory leanness is the main point of trade-off between lean and resilience.

Contributions and limitations

The present study provides contributions to lean literature in the following ways. First, the results of the empirical analysis provide further confirmation of the hypothesis that lean adoption can lead to an improved business performance, in accordance with previous literature (Fullerton et al. 2003; Galeazzo and Furlan, 2018; Hofer et al., 2012; Yang et al., 2011). Moreover, the work shows evidence of a different behavior of lean firms based on the extent of their leanness adoption, supporting the line of research that associates performance improvements only to the joint adoption of several lean practices (Losonci and Demeter, 2013). In particular, the study contributes to extending the validity of the results to the specific context of Italian manufacturing firms.

The original aspect of this work lies however in its second contribution. In fact, this work supports the hypothesis that the positive impact of lean adoption on performance is retained even through periods of high variability. The insight provides an argument in favor of lean adoption, supporting the idea that efficiency and resilience are not mutually exclusive objectives. In addition, the method adopted represents a further distinctive element: the study differentiates itself from previous works by focusing on financial rather than operational resilience (Birkie, 2016), and by adopting and indicator of turbulence that reflects the variability of business performance, rather than the dynamism of demand (Azadegan et al., 2013).

In conclusion, the value of the study lies in the original perspective it brings to the popular research line studying lean and performance connections. In addition, the results appear valid, as they are confirmed by three different indicators of financial performance and by different sets of regressions. However there are also limitations to be recognized, that require to be cautious in interpreting the results, and at the same time provide opportunities for future works.

First of all, a limitation of this work is that the information regarding the degree of business performance variability, and consequently the presence of periods of turbulence, had to be computed indirectly, as primary level information from firms on the topic was not available. Future works could resolve this issue by gathering primary data about firm experiences with specific crisis situations of different intensities, in addition to information about their individual lean adoption.

Secondly, this study assessed the resilience of a firm as a superior financial performance in a given period of time, measured through ROA, ROS and ROI. And while it’s not uncommon in literature to interpret resilience as a relatively superior performance (Markman et al., 2014; Santoro et al., 2020), and to measure it employing financial indicators (De Carvalho et al., 2016), it should be considered that a concept as complex and multi-faceted as resilience is difficult to capture through financial indicators only. This observation poses an opportunity for future research to expand on the topic, considering different measures of resilience, or employing jointly indicators of financial and operational performance. Providing assessments with different points of view could further the investigation, confirming or denying the findings in this study.

Finally, while this research supports the idea that lean and resilience may be compatible, it also raises some questions on the effect that different categories of lean practices may have, for example those that cause inventory reductions. The reduced size of the sample prevented from studying the impact associated to different bundles of practices, but future research could use samples of larger dimension, and analyze empirically which bundles of lean practices are related to resilience building, and which instead may represent limitations. Gaining a deeper understating of the possible synergies among the paradigms could provide fundamental managerial insights, to help navigate the equilibrium between the efficiency provided by leanness and the increasing need to be resilient to sustain performance over time in increasingly uncertain business environments.

BIBLIOGRAPHY

Azadegan, A., Patel, P.C., Zangoueinezhad, A., Linderman, K., 2013. *The effect of environmental complexity and environmental dynamism on lean practices*. Journal of Operations Management 31, 193–212.

Azevedo, S.G., Carvalho, H., Cruz-Machado, V., 2016. *LARG index: A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain*. Benchmarking 23, 1472–1499.

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, 5346-5366.

Bianchi, F., 2010. *Introduzione*, in: Bianchi, F., 2010, *Visual management: le 5S per gestire a vista.* Guerini Next, Milano.

Bicheno, J., Holweg, M., 2016. *The Lean toolbox: the essential guide to Lean transformation, 5th edition* . PICSIE Books, Buckingham.

Birkie, S.E., 2016. *Operational resilience and lean: in search of synergies and trade-offs*. Journal of Manufacturing Technology Management 27, 185–207.

Birkie, S. E., Trucco, P., 2016. *Understanding dynamism and complexity factors in engineer-to-order and their influence on lean implementation strategy*. Production Planning & Control 27, 345-359.

Brambor, T., Clark, W. R., & Golder, M., 2006. *Understanding interaction models: Improving empirical analyses.* Political Analysis 14, 63-82.

Buer, S.V., Strandhagen, J.O., Chan, F.T.S., 2018. *The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda*. International Journal of Production Research 56, 2924–2940.

Cabral, I., Grilo, A., Cruz-Machado, V., 2012. *A decision-making model for lean, agile, resilient and green supply chain management.* International Journal of Production Research 50, 4830-4845.

Carvalho, H., Duarte, S., Cruz Machado, V., 2011. *Lean, agile, resilient and green: divergencies and synergies*. Lean Six Sigma Journal 2, 151–179.

Chavez, R., Gimenez, C., Fynes, B., Wiengarten, F. and Yu, W., 2013. *Internal lean practices and operational performance: The contingency perspective of industry clockspeed*. International Journal of Operations & Production Management 33, 562-588.

Chopra, S., Sodhi, M., 2014. *Reducing the risk of supply chain disruptions*. MIT Sloan management review 55, 72-80.

Christopher, M., Peck, H., 2004. *Building the Resilient Supply Chain.* International Journal of Logistics Management 15, 1–14.

Cua, K. O., McKone-Sweet, K. E., & Schroeder, R. G., 2001. *Relationships between Implementation of TQM, JIT, and TPM and Manufacturing Performance*. Journal of Operations Management 19, 675-694.

Dal Pont, G., Furlan, A., Vinelli, A., 2008. *Interrelationships among lean bundles and their effects on operational performance.* Operations Management Research 1, 150–158.

De Carvalho, A. O., Ribeiro, I., Silva Cirani, C. B., & Cintra, R. F., 2016. *Organizational resilience: a comparative study between innovative and non-innovative companies based on the financial performance analysis.* International Journal of Innovation, 4, 58-69.

De Sanctis, I., Ordieres Meré, J., Ciarapica, F.E., 2018. *Resilience for lean organisational network*. International Journal of Production Research 56, 6917–6936.

DesJardine, M., Bansal, P., & Yang, Y., 2019. *Bouncing back: Building resilience through social and environmental practices in the context of the 2008 global financial crisis.* Journal of Management 45, 1434-1460.

Eroglu, C., Hofer, C., 2014. *The effect of environmental dynamism on returns to inventory leanness.* Journal of Operations Management 32, 347-356.

Fullerton, R.R., McWatters, C.S., Fawson, C., 2003. *An examination of the relationships between JIT and financial performance*. Journal of Operations Management 21, 383–404.

Furlan, A., 2018. *Allineamento per il successo: come creare una trasformazione lean sostenibile.* Guerini Next, Milano

Furlan, A., Vinelli, A., Dal Pont, G., 2011. *Complementarity and lean manufacturing bundles: an empirical analysis*. International Journal of Operations & Production Management 31, 835–850.

Galeazzo, A., Furlan, A., 2018. *Lean bundles and configurations: a fsQCA approach.* International Journal of Operations & Production Management 38, 513-533

Garza-Reyes, J.A., 2015. *Lean and green – a systematic review of the state of the art literature*. Journal of Cleaner Production 102, 18–29.

Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V., 2015. *Lean, green and resilient practices influence on supply chain performance: interpretive structural modeling approach*. International Journal of Environmental Science and Technology 12, 15–34.

Hanke, J. E., Wichern, D. W., 2009. *Business forecasting 9th ed*. New Jersey.

Hicks, B.J., 2007. *Lean information management: Understanding and eliminating waste.* International Journal of Information Management 27, 233-249.

Hofer, C., Eroglu, C., Rossiter, 2012. *The effect of lean production on financial performance: The mediating role of inventory leanness*. International Journal of Production Economics 138, 242–253.

Holweg, M., 2007. *The genealogy of lean production*. Journal of Operations Management 25, 420–437.

Hopp, W.J., Spearman, M.L., 2004. *To Pull or Not to Pull: What Is the Question?* Manufacturing & Service Operations Management 6, 133–148.

Inman, R.A., Green K.W., 2018. *Lean and green combine to impact environmental and operational performance*. International Journal of Production Research, 56, 4802-4818

Ivanov, D., Sokolov, B., Dolgui, A., 2014. *The Ripple effect in supply chains: trade-off ‘efficiency-flexibility-resilience’ in disruption management.* International Journal of Production Research 52, 2154–2172.

Katko, N., Furlan, A., 2018. *Capitolo 7 – Lean accounting: prendere le giuste decisioni per realizzare l’allineamento*, in: Furlan, A., 2018. *Allineamento per il successo: come creare una trasformazione lean sostenibile*. Guerini Next, Milano

Losonci, D., Demeter, K., 2013. *Lean production and business performance: international empirical results.* Competitiveness Review: An International Business Journal.

Lotfi, M., Saghiri, S., 2018. *Disentangling resilience, agility and leanness: Conceptual development and empirical analysis*. . Journal of Manufacturing Technology Management 29, 168–197.

Markman, G. M., Venzin, M., 2014. *Resilience: Lessons from banks that have braved the economic crisis—And from those that have not*. International Business Review 23, 1096-1107.

Maslaric, M., Backalic, T., Nikolicic, S., & Mircetic, D., 2013. *Assessing the trade-off between lean and resilience through supply chain risk management.* International Journal of Industrial Engineering and Management 4, 229-236.

McCarthy, D., Rich, N., 2015. *Chapter Two - The Lean TPM Master Plan*, in: McCarthy, D., Rich, N. (Eds.), *Lean TPM (Second Edition).* Butterworth-Heinemann, Oxford, pp. 27–54.

Mohammaddust, F., Rezapour, S., Farahani, R.Z., Mofidfar, M., Hill, A., 2017. *Developing lean and responsive supply chains: A robust model for alternative risk mitigation strategies in supply chain designs.* International Journal of Production Economics 183, 632–653.

Nowell, B., Bodkin, C.P., Bayoumi, D., 2017. *Redundancy as a strategy in disaster response systems: A pathway to resilience or a recipe for disaster?* Journal of Contingencies and Crisis Management 25, 123–135.

Pal, R., Torstensson, H., Mattila, H., 2014. *Antecedents of organizational resilience in economic crises—an empirical study of Swedish textile and clothing SMEs*. International Journal of Production Economics 147, 410–428.

Piercy, N., Rich, N., 2009. *Lean transformation in the pure service environment: the case of the call service centre.* International Journal of Operations & Production Management 29, 54–76.

Ponomarov, S.Y., Holcomb, M.C., 2009. *Understanding the concept of supply chain resilience.* International Journal of Logistics Management 20, 124–143.

Purvis, L., Spall, S., Naim, M., Spiegler, V., 2016. *Developing a resilient supply chain strategy during 'boom' and 'bust.'* Production Planning & Control 57, 579-590.

Rother, M., Shook, J., 2009. *Learning to see: value-stream mapping to create value and eliminate muda.* Lean Enterprise Institute, Cambridge, MA.

Ruiz-Benitez, R., López, C., Real, J.C., 2019. *Achieving sustainability through the lean and resilient management of the supply chain*. International Journal of Physical Distribution & Logistics Management 49, 122–155.

Ruiz-Benítez, R., López, C., Real, J.C., 2018. *The lean and resilient management of the supply chain and its impact on performance.* International Journal of Production Economics 203, 190–202.

Ruiz-Benitez, R., López, C., Real, J.C., 2017. *Environmental benefits of lean, green and resilient supply chain management: The case of the aerospace sector.* Journal of Cleaner Production 167, 850–862.

Santoro, G., Messeni-Petruzzelli, A., & Del Giudice, M., 2020. *Searching for resilience: the impact of employee-level and entrepreneur-level resilience on firm performance in small family firms*. Small Business Economics, 1-17.

Scholten, K. and Schilder, S., 2015. *The role of collaboration in supply chain resilience*, Supply Chain Management, Vol. 20 No. 4, pp. 471-484

Shah, R., Ward, P.T., 2003. *Lean manufacturing: context, practice bundles, and performance.* Journal of Operations Management 21, 129–149.

Sheffi, Y., Rice, J., Jr, 2005. *A Supply Chain View of the Resilient Enterprise*. MIT Sloan Management Review 47.

Slack, N., Brandon-Jones, A., Johnston, R., 2016. *Operations management, 8th edition*. Pearson, Harlow, England London New York.

Webb M.J., Mandelli S., Melioli M., 2018. *Capitolo 2 – Allineare l'azione commerciale alle aspettative del cliente*, in: Furlan, A., 2018. *Allineamento per il successo: come creare una trasformazione lean sostenibile*. Guerini Next, Milano

Womack, J.P., Jones, D.T., 2003. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation.* New York, Free Press.

Womack, J.P., Jones, D.T., Roos, D., 1990. *The machine that changed the world.* New York, Free Press

Yang, M. G. M., Hong, P., 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, 251-261.

Zu'bi, M. F., 2015. *Examining the impact of lean practices on flexibility performance: The moderating effect of environmental dynamism*. Engineering Management Research 4, 54-69.

Sitography

AIDAF, 2020. *Le imprese familiari in Italia.* Viewed on 10/09/2020. <https://www.aidaf.it/aidaf/le-imprese-familiari>

ISTAT, 2015. *Classificazione delle attività economiche ateco 2007.* Viewed on 05/09/2020. <https://www.istat.it/it/archivio/17888>

ISTAT, 2020. *Competitività dei settori produttivi.* Viewed on 06/09/2020 <https://www.istat.it/it/competitivita>

Lean Enterprise Institute, 2006. *Build your "house" of production on a stable foundation*. Viewed on 22/05/2020. <https://www.lean.org/common/display/?o=799>

Lean Enterprise Institute, 2020. *Lean lexicon: Andon*. Viewed on 22/05/2020. <https://www.lean.org/lexicon/andon>

Lean Enterprise Institute, 2020. *Lean lexicon: Heijunka,* Viewed on 28/05/2020. <https://www.lean.org/lexicon/heijunka>

APPENDIX

Appendix 1

In order to determine periods of turbulence in the different industries, an adjustment was made to the original database, excluding those industries for which only a limited number of observations was available. The table below shows the number of observations available for each ATECO 2-digit industry sub-sample.

Industry	*Sample firms per industry*	*Lean firms per industry*	*% Sample firms per industry*	*% Italian firms per industry*	*% Lean firms per industry*
10 - Food industry	22	6	5%	9%	3%
11 - Beverage industry	9	4	2%	1%	2%
13 - Textile industry	9	2	2%	4%	1%
14 - Clothing industry	6	1	1%	5%	0%
15 - Leather goods	6	0	1%	5%	0%
16 - Wood products	9	2	2%	3%	1%
17 - Paper manufacturing	9	5	2%	2%	2%
18 - Printing industry	9	4	2%	2%	2%
20 - Chemical products	19	8	4%	3%	4%
21 - Pharmaceutical industry	6	4	1%	1%	2%
22 - Rubber products	32	19	7%	5%	9%
23 - Non metal products	14	4	3%	4%	2%
24 - Steel products	14	5	3%	2%	2%
25 - Metal products	86	39	19%	23%	18%
26 - Telecommunications equipment	8	5	2%	3%	2%
27 - Electric appliances	37	24	8%	4%	11%
28 - Machinery equipment	101	63	23%	12%	29%
29 - Motor vehicles	6	2	1%	1%	1%
30 - Other transport vehicles	4	2	1%	1%	1%
31 - Furniture	23	12	5%	4%	6%
32 - Other manufacturing	19	7	4%	3%	3%

Appendix 2

The table below provides a summary of the descriptive statistics for the variables employed in the 7 models of multiple linear regressions in chapter 5.

Variable	***Type***	***Observations***	***Min***	***Max***	***Mean***	***Median***
Lean	Categorical	237	0	1		
Lean recent	Categorical	237	0	1		
Lean experienced	Categorical	237	0	1		
Lean beginner	Categorical	237	0	1		
Lean advanced	Categorical	237	0	1		
Industry: ATECO 10	Categorical	237	0	1		
Industry: ATECO 20	Categorical	237	0	1		
Industry: ATECO 24	Categorical	237	0	1		
Industry: ATECO 27	Categorical	237	0	1		
Industry: ATECO 28	Categorical	237	0	1		
ROA	Continuous	237	-1,53	20,00	6,29	5,49
ROS	Continuous	237	-1,72	17,55	5,73	4,97
ROI	Continuous	235	-1,72	27,64	11,01	10,08
Coefficient of variation - ROA	Continuous	236	0,08	27,96	1,30	0,44
Coefficient of variation - ROS	Continuous	236	0,06	393,48	2,93	0,42
Coefficient of variation - ROI	Continuous	214	0,03	37,13	1,09	0,42
Size	Continuous	237	0,75	3,17	1,81	1,79
Past performance - ROA	Continuous	229	-16,71	37,25	4,47	3,75
Past performance - ROS	Continuous	228	-11,45	23,87	3,80	3,61
Past performance - ROI	Continuous	214	-16,50	29,81	7,78	6,45