Effects of quality management and process innovation on productivity in Spanish manufacturing firms

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ABSTRACT

This paper analyses the effect of process innovation and quality management on productivity in Spanish manufacturing firms. For this purpose, we take identify and explain issues such as quality management systems, product standardization, complexity of the production process system and some considerations about technological innovation. This study uses data from the survey of business strategies (ESEE) of Spanish manufacturing firms, demonstrating the positive effect of all these factors on productivity, especially of quality management techniques. We discuss the results and get new findings from the review of the academic literature, the analysis and the proposals for the technology improvement.

Keywords: productivity, quality management, product standardization, innovation, manufacturing.

1. INTRODUCTION

Today everything is in continuous development, especially those aspects related to technology, both in everyday life, as in the workplace. The current firms have to improve every day. The improvements can be shown from the staff, where workers continue to expand their knowledge through courses or training for new technologies, to manufacturing processes, where new machines, new techniques or even new materials are always appearing. This paper analyzes the mentioned issues and with particular focus the quality management and the innovation.

If we focus on quality, we could say that there is a concern for everything with which it has a relationship and for its integration into production systems. It is not enough to obtain quality, but it must be at a low cost, which forces companies to optimize products and processes. All this together with the high competitiveness of the market, forces to improve the organization and management of all the processes of the firm. This goes along the lines of what is known as Total Quality Management or TQM (Cuatrecasas Arbós and González Babón, 2017).

On the other hand, innovation is an issue that in recent years has become crucial for the competitiveness of firms. Firms have the need to continue expanding or modifying what they offer. But to carry out this innovation process they have to value their options. Not all firms have the resources and capabilities to develop a new product or a change in the production process. This is why many firms opt for technological collaboration (Minguela-Rata et al., 2014).

This work tries to make a contribution to quality management, manufacturing systems or innovation, both of the product and the production process. Where in turn is analyzed its relationship with productivity in Spanish manufacturing firms.

The purpose of this paper is to study the effects of quality management systems and manufacturing systems on productivity in Spanish manufacturing firms by analyzing the data from the survey of business strategies (ESEE).

At the same time, we consider issues about innovations of firms both product and process, where they influence variables such as the use of new techniques, new software and new machines.

We use Excel and Stata 9.0 to manage ESEE data. These programs allow us to analyze variables related to the topics that concern with this paper. Among them, the most used method is the ordinary least squares method or linear multiple regressions.

The paper has six sections. The first is the introduction; the second is devoted to the literature review; the third focuses on the methodology used in the analyzes; the fourth comments the current situation of Spanish manufacturing firms based on other research articles; the fifth is dedicated to exposing the results obtained in the estimates made using the ESEE data; and the last one concludes.

2. LITERATURE REVIEW

The intention of this section is to study the related literature and get a prior idea about the concepts that are the basis of this paper: quality management, innovation and production systems. Taking into account at the same time the relation of these same ones with the productivity of the firms.

2.1. Quality Management

As it is well described in (Griful-Ponsati and Canela-Campos, 2005), quality, despite being a key aspect for any company, is a difficult concept to define. Since depending on the context you can find definitions oriented towards the product, towards the use of the product, towards production, towards the value of the product or even, in a more ideological way, towards business excellence.

"Total Quality Management (TQM) as a philosophy, seeks to obtain the global commitment of organization through its participation to optimize its effectiveness and flexibility, improve products and services, reduce costs, increase the number of clients, develop more satisfied employees, improve their performance and contribute to productivity" (Demuner Flores and Mercado Salgado, 2011).

Firms have access to numerous quality management systems, with which they can assess their strengths and weaknesses, or with which they can decide and plan the actions they are going to carry out. Within these systems there are guidelines that aim to formalize all these systems. Within these guidelines are the International Standards Organization (ISO) and the models of excellence. ISO standards are commonly used, because they have achieved a reputation for being easy and effective. The most used ISO standards are those of the ISO 9000 family. Regarding the models of excellence, the most used are the EFQM (European Foundation for Quality Model) in Europe and the MBNQA (Malcom Baldrige National Quality Award) in the United States of America.

Regarding ISO international standards related to quality, there are a lot of standards that depend on the field of application and the activity that is carried out. Some of the most used of those related to the ISO 9000 family are the following:

• UNE-EN ISO 9000: 2015 - Quality Management Systems. Principles and vocabulary

• UNE-EN ISO 9001: 2015 - Quality Management Systems. Requirements

• UNE-ISO / TS 9002: 2017 - Quality Management. Guidelines for the application of ISO 9001: 2015 Standard.

• UNE-EN ISO 9004: 2018 - Quality Management. Quality of an organization. Orientation to achieve sustained success.

• UNE-EN ISO 19011: 2018 - Guidelines for the audit of management systems.

That quality is an important factor is widely known, but there are also studies that relate it to other agents. In (Arraut-Camargo, 2011) the concepts of quality and innovation are related, where the author affirms that the firms, to compete in the markets, depend on their relations with both sources of competitive advantage. This study analyzes firms that apply the ISO 9000: 2000 standard, the one available at the time of its realization, where the results reflect that the ISO 9000 system has a positive impact on firms. As a conclusion, it states that a quality system as organizational innovation of the firm affects positively both the quality and productivity of the same.

In spite of all this, there are also authors with opposite points of view. Some such as (Fisher, 1991), (Becker, 1993) or (Salegna and Fazel, 1995) state that from their point of view TQM has no effect on productivity. In any case, the date on which these studies were carried out should be highlighted in the last decade of the 20th century, since they could be obsolete. In any case, it is thanks to these different points of view that this study may have a greater interest.

2.2. Innovation and R&D

Innovation is an issue that in recent years has become crucial for the competitiveness of firms. Frías (2006) considers innovation as the implementation of a new or improved product and / or service or process; a new marketing system or a new organizational method such as: business practices, work organization and external relations. That is, the minimum requirements for an innovation are that the product, process, marketing systems or organizational method being new or significantly new for the firm.

A topic closely related to innovation is the investment of firms in research and development (R & D). Regarding this topic there is a lot of related literature. Griffith et al. (2004) show that R & D stimulates the growth through innovation and technology transfer. Barge-Gil and López (2011) affirm that R & D is the main source of innovation and is a determining factor in the productivity increases of firms.

Ortiz (2006) points out that innovation can be grouped into five categories: product development; process development; design engineering; design and redesign of machine and equipment; and organization of production. Within these categories there are different types of variables, for example: within the innovation activities related to the product, a current one can be modified, the competition can be copied or a completely new one can be developed; and the same could happen with the type of process. All these activities can have a great impact at the strategic level of the firm, since according to the emphasis that there is on a certain type of innovation activity and the frequency with which it is carried out, it is an important element in the choice of the technological strategy of the firm. Sánchez-Sellero et al. (2015) shows that innovation in product and production process improves the application and production of required knowledge that improves productivity of manufacturing firms.

If we focus on product innovations, another important factor is the degree of novelty, this implies that, depending on the degree of originality, the risk and uncertainty will vary to a greater or lesser extent. Based on this, we can distinguish between radical innovations, where the product is totally new and entails greater market risk and uncertainty, and incremental innovations, where improvements are made to existing products with a lower risk than the previous ones (Minguela-Rata et al., 2014). This paper concludes that the large firms are more inclined to innovate in product, but when they focus on the type of product innovation, the study shows that it is medium-sized firms that tend to perform radical innovations, while small and large innovations are characterized by incremental innovations.

Finally, another option that allows improving the innovation of firms is the cooperation and absorption of information. R&D activities boost the generation of new knowledge and absorptive capacity (Sánchez-Sellero et al., 2014). Especially, external cooperation in innovation and the assimilation of knowledge allow firms to act in an agile and effective way to change the needs of customers, as well as to having the ability to improve their production processes (Dobrzykowski et al., 2015).

2.3. Production systems: complexity and agile production

There is a concept with great relevance within the production of manufacturing firms: the agile production or Lean Manufacturing. This concept goes back to the decade of 1950, of the Toyota automobile factory, the Toyota Production System (TPS) was born, which is the basis of what we know as lean manufacturing (Padilla, 2010).

Since the birth of TPS, many tools and techniques of agile production have been widely used, such as: Just in Time (JIT), cellular manufacturing, total productive maintenance, the Single-Minute Exchange of Dies (SMED), production leveling, the Kaizen method (continuous improvement) or the PokaYoke (fail-safe). These activities are oriented towards the Toyota Production System (TPS). This system provides a systematic approach of production, trying to identify and eliminate the activities that cause waste of any type of resource (time, materials, machinery, etc.) through continuous improvement (Rahani and Al-Ashraf, 2012).

Despite the great confusion regarding the explanations and interpretations of the concept, the fact that agile manufacturing is a multidimensional concept with different facets, has led to the appearance of numerous definitions. Each of them tries to emphasize a particular dimension or aspect. There are definitions based on their results (flexibility, innovation, etc.) and based on their operation or implementation (cooperation, technological use, etc.) (Vázquez-Bustelo and Avella-Camarero, 2006).

Agile production combines a set of techniques that seek to improve and optimize the operating processes of any industrial firm, regardless of its size, with the objective of minimizing waste (time, resources, ...) (Padilla, 2010).

According to its result, agile production is not only based on flexibility and responsiveness, but also responds quickly to the dynamic demands of customers, has to consider the cost, the quality of products and services. To do this correctly, firms must have, among other things, a good capacity to design new products and processes and a good collaboration with suppliers and other agents in the supply chain (Gunasekaran, 1999a, 1999b); (Gunasekaran and Yusuf, 2002).

As highlighted in (Martínez-Sánchez et al., 2018), Spanish manufacturing firms, to achieve agility, are focusing efforts on organizational support for innovation, production capabilities such as flexibility, external and internal innovation capabilities. This study shows that the most agile firms are distinguished from the least agile, among other reasons, because they have developed some capacities for production management, product innovation and external cooperation in innovation. In addition, he affirms that this external cooperation is capable of moderating production flexibility, allowing firms with less flexible production systems to achieve greater capacity for agility.

2.4. Spanish manufacturing firms

We intend to make a small general analysis of some keys of the productive systems in Spanish manufacturing firms. This paper focuses mainly on three issues: quality management, innovation and production systems.

As for standardization and quality management work, it is clear that it is a concept that allows improving the product or service offered by the company. Through the application of techniques such as QFD (Quality Function Deployment), FMEA (Failure Modes and Effects

Analysis) or excellence models such as EFQM (European Foundation Quality Management) it allows companies to analyze the procedures and improvements to continue obtaining the same or even better results, while at the same time achieving a low cost. Giménez Espín et al. (2014) make a study for Spanish manufacturing companies where they have made the following observation: "it has been observed that TQM (Total Quality Management) is an effective means for companies to increase their competitiveness". This improvement in competitiveness is based on excellence and confidence in the products and services of the organization. Therefore, the TQM is a philosophy that establishes principles for management that maximize the competitiveness of a firm through the continuous improvement of the quality of its products, services, personnel, processes and environment.

In the case of innovation, the effect of investing in renewing and improving both the product and the production system is logically positive. Technology today advances at a huge speed and that is why everything is in continuous innovation. There are always new ways to perform the same process or a machine that allows you to operate with greater efficiency. Nowadays with all the advance of wireless communications, the industrial sector has been revolutionized. Buisán and Valdés (2017) consider that this innovation has already emerged the term of the fourth industrial revolution, the industry 4.0. All this has been occurring since the late twentieth century with all the technological changes and the digitalization of the industry. Concepts such as big data, advanced and collaborative robotics or sensory, are affecting and will affect the Spanish and global industry.

All this in the end is connected, everything progresses and it is clear that these concepts go hand in hand. Añaguari Yarasca and Gisbert Soler (2016) summarize perfectly the pillars of agile production.

1. The philosophy of continuous improvement.

2. Total control of the total quality.

3. The elimination of waste.

4. Harnessing all the potential along the value chain.

5. The participation of the operators.

Hernández Matías and Vizán Idolpe (2013) make a good review of the situation of the productive systems of Spanish companies, focused mainly on Lean Manufacturing or agile production. This study records that "in most cases the use of Lean techniques have given good or very good results".

Likewise, Rosell-Martínez and Sánchez-Sellero (2012) concludes that capital-intensive and R&D-intensive sectors offer the most convenient conditions for innovation to generate technical progress. Whereas, Hernández Matías and Vizán Idolpe (2013) appreciate which are the main improvements obtained with the application of Lean techniques. These parameters with higher improvements are: increase of productivity, reduction of costs, reduction of production terms and increase of flexibility. In any case, the application of this concept of agile production in Spanish firms also encounters obstacles. Mainly, they are from the internal scope of the firm, such as the resistance to change or the training of personnel and their deficient training to face the cultural change demanded by the new techniques.

The variables that appear throughout this paper, specifically, the product standardization and the complexity of the production system, are highly related to each other and to the concept of agile production. Hernández Matías and Vizán Idolpe (2013) comment on which of the Lean techniques applied in Spanish manufacturing firms are those that provide a greater relationship between benefits and costs. Among the best appears standardization. That is, firms can extract more value from their production if they implement a higher standardization in their products and their production system. The standardization allows to optimize the work method and to adjust the rhythm of production, according to the client demand and to the needs and capacities of the firm.

The elements introduced in the variable CPS (Complexity of the Productive System), have a close relationship with all the concepts that are being discussed. For example, the use of flexible systems, such as flexible work cell organization, is one of the basic measures within the concept of agile production. On the other hand, the use of internal communication systems is another basic instrument of this type of production. The use of LAN (Local Area Network) is one of the bases of this internal communication, and it supports systems such as ERP (Enterprise Resource Planning) or MES (Manufacturing Execution Systems) that are widely used, today, to organize the resources of the firm and control the production times. On the other hand, the design is fundamental within this agile production model, to improve continuously both the product and the manufacturing process (Hernández Matías and Vizán Idolpe, 2013).

It is clear that in the end all aspects are related under the concept of agile production, that is, both good quality management and a good innovation plan are needed to improve the production process, reducing costs and minimizing the waste of resources. The future of Spanish manufacturing firms is to begin to apply all these types of measures, if they are not already doing so, and to continue developing them, if they are already using them.

2.5. Hypothesis

We propose hypotheses based on the literature review. Table 1 includes the effects of different factors on productivity.

Table 1: Hypothesis

NUMBER	FACTOR	SIGN
1	Product standardization	Positive
2	Standardization and quality management	Positive
3	Process innovation	Positive
4	Complexity of the productive system	Positive

3. DATA, MODEL AND METHODOLOGY

3.1. Information analysis

Nowadays it is very important for firms to get information that may influence on their productivity. This is a basic part of quality management and is reflected in the ISO 9001:2015 standard about quality management systems. Firms that wish to have a good quality management system can follow the requirements of this standard. Section 7.5 of this ISO standard, regarding the collection of information, it records what information firms should collect. In addition, it also mentions the importance, for the planning and operation of the quality management systems, of the external information.

Surveys are an effective method of gathering external information that can be useful for the productive sphere. The ESSE survey has data from a large number of Spanish manufacturing firms. Among all of them, there is useful information for the analysis of the relationship of quality management with the productivity of firms. There are variables in this survey that, from the point of view of ISO 9001:2015, are quite interesting. The size of the organization and its type of activities, processes, products and services; the complexity of the processes and their interactions; and the competence of people, are some of them. We will discuss and study in detail these factors throughout this paper.

3.2. Variables to study

The data available and used belong to 1525 Spanish manufacturing firms, which belong to 20 manufacturing sectors as shown in (Table 2: Firms by sector). The source of information is the ESEE of 2016. This table shows the number of firms that have been analyzed by each sector, the percentage of the total to which they are equivalent and the different sectors studied.

Table 2: Firms by sector

Number of firms by sector		
SECTORS	**NUMBER**	**PERCENTAGE**
1. Meat industry	65	4,26%
2. Food products and tobacco	186	12,20%
3. Drinks	33	2,16%
4. Textiles and clothing	100	6,56%
5. Leather and footwear	49	3,21%
6. Wood industry	47	3,08%
7. Paper industry	69	4,52%
8. Graphic arts	57	3,74%
9. Chemical industry and pharmaceutical products	112	7,34%
10. Rubber and plastic products	80	5,25%
11. Non-metallic mineral products	99	6,49%
12. Ferrous and non-ferrous metals	51	3,34%
13. Metallic products	195	12,79%
14. Agricultural and industrial machines	94	6,16%
15. Computer, electronic and optical products	26	1,70%
16. Machinery and electrical equipment	55	3,61%
17. Motor vehicles	75	4,92%
18. Other transport material	31	2,03%
19. Furniture industry	61	4,00%
20. Other manufacturing industries	40	2,62%
TOTAL	**1525**	**100,00%**

Within the data of the survey, there are annual and variable variables that are four-year. That is why there are data from the exercise of two different years. The intention to collect data from two different years is to have them as up-to-date as possible.

For the four-year periods, the most recent data are for the year of 2014 and for the year for 2016. It is considered that the value taken by the four-year variables is the same in each of the years after the one in which the questionnaire until such time as a new response is obtained. Consequently, the 2016 value of the four-year variables is considered as the response given in 2014.

In the following table (table 3: Variables and temporal classification) the reader can see the variables that have intervened in the study and the variables, original ESEE, which form the previous ones. In addition, it appears what type they are, quadrennial or annual, and the year of exercise from which they were taken.

Table 3: Variables and temporal classification

Name of the variable	Code of the variable	ESEE variables	Type of variable	Year
Value added	VA	Production and other incomes	ANNUAL	2016
		Intermediate consumption	ANNUAL	2016
Cost of the input labor	CLAB	Labor costs	ANNUAL	2016
		Total staff	ANNUAL	2016
Capital	CAP	Land and buildings	ANNUAL	2016
		Property, plant and equipment (without land and buildings)	ANNUAL	2016
Number of workers	NLAB	Total staff	ANNUAL	2016
Product standardization	PS	Product standardization	QUADREN	2014
Standardization and quality management	SQM	Standardization and quality control	QUADREN	2014
Complexity of the productive system	CPS	Use of robotics	QUADREN	2014
		Use of local area network	QUADREN	2014
		Use of flexible systems	QUADREN	2014
		Utilization machine tools numerical control	QUADREN	2014
		Use of CAD	QUADREN	2014
		Design	QUADREN	2014
		Standardization and quality control	QUADREN	2014
		Services scientific and technical information	QUADREN	2014
		Imported technology assimilation effort	QUADREN	2014
		Market and marketing studies	QUADREN	2014
Innovation of the production process	INPRC	Process innovations by new equipment	ANNUAL	2016
		Process innovations by new techniques	ANNUAL	2016
		Process innovations by computer programs	ANNUAL	2016

In the previous table (table 3: Variables and temporal classification) the reader can see, in the first two columns, all the variables used in the study with their full names and acronyms. On the right, each one of the variables of the ESEE used in the formation of the variables of this study is detailed, most of them are explained in the web of the SEPI foundation:

• VA: It is about added value. It is defined as the sum of sales, the change in inventories and other management income, less purchases and external services. Unit: euro

• CLAB: It is the labor expense for each worker. It is constructed with the quotient of the total labor expense among the total number of personnel of the company. Unit: euro / worker

• NLAB: It refers to the total number of workers in the company. Unit: worker

• CAP: This is the capital of the company. It is built by obtaining all the tangible assets of the company. Unit: euro

• PS: It refers to the product standardization. It is obtained by means of a variable of the survey measured in high standardization and low standardization.

- Value 1 = High standardization.
- Value 0 = Low standardization.

• SQM: It is the use of standardization and quality management systems in the firm.

- Value 1 = Use of standardization and quality management systems.
- Value 0 = Does not use standardization and quality management systems.

• INPRC: This variable measures innovation in the productive process of firms. The degree of innovation ranges from 0 to 3 and takes into account the use of new machinery, new computer programs oriented to industrial processes and the use of new techniques or methods.

- Value 0 = Does not use any of the mentioned systems.
- Value 1 = Use 1 of the mentioned systems.
- Value 2 = Use 2 of the mentioned systems.
- Value 3 = Use 3 of the mentioned systems.

• CPS: This variable, created with the sum of several responses to the survey, measures the degree of complexity of the productive system. It is the sum of 10 productive variables (use of robotics, possession of local area network, management of flexible systems, CNC machinery, use of CAD, good design planning, standardization and quality management systems, scientific information services and technical, effort in the assimilation of imported technology, and conducting market and marketing studies). Same functioning as the INPRC variable, but with 10 variables instead of 3, the range goes from 0 to 10, depending on the options available to the firm.

3.3. Model and methodology

The method of ordinary least squares (OLS), also commonly known as linear regression method, is the method chosen to perform most of the estimates of this work.

To carry out the study, and analyze the technological factors that affect the productivity of firms, we have proposed several linear regressions. In order to apply the method well, first of all, we have distinguished the variables between quantitative and qualitative (Table 4: Distinction of the variables).

Table 4: Distinction of the variables

Quantitative	Qualitative
VA	PS
CLAB	SQM
NLAB	CPS
CAP	INPRC

This distinction is made because the treatment that is made of the variables is different depending on the type of variable in question. This case is based on a Cobb-Douglas production function. This implies that there are quantitative variables that are exponential.

In the model we propose, these quantitative variables are non-linear parameters, but easily linearizable with a small conversion. This small transformation allows us to perform the estimation by the ordinary least squares method.

On the other hand, the qualitative variables take values 0 or 1. These variables do not require any kind of prior treatment or adaptation before their use in the OLS method. There are two qualitative variables among them, that require a more detailed explanation. The variable CPS (Complexity of the Productive System) and the INPRC (Innovation of Process), have a peculiarity, both are an aggregation of variables 0-1. In the case of CPS, it is the sum of 10 variables, while INPRC adds only 3 different variables. This is why their ranges of values, as already indicated before in the explanation of each variable, range from 0 to 10, in the case of CPS, and from 0 to 3, in the case of INPRC.

Several estimates have been made with all these variables, varying the variables used in each of them. This allows us to analyze the contributions and compare the results. Next, we can see the expressions of the production functions of the linear regressions performed (table 5: Regression functions) where α is the constant, β the coefficient of each variable and ε is the error.

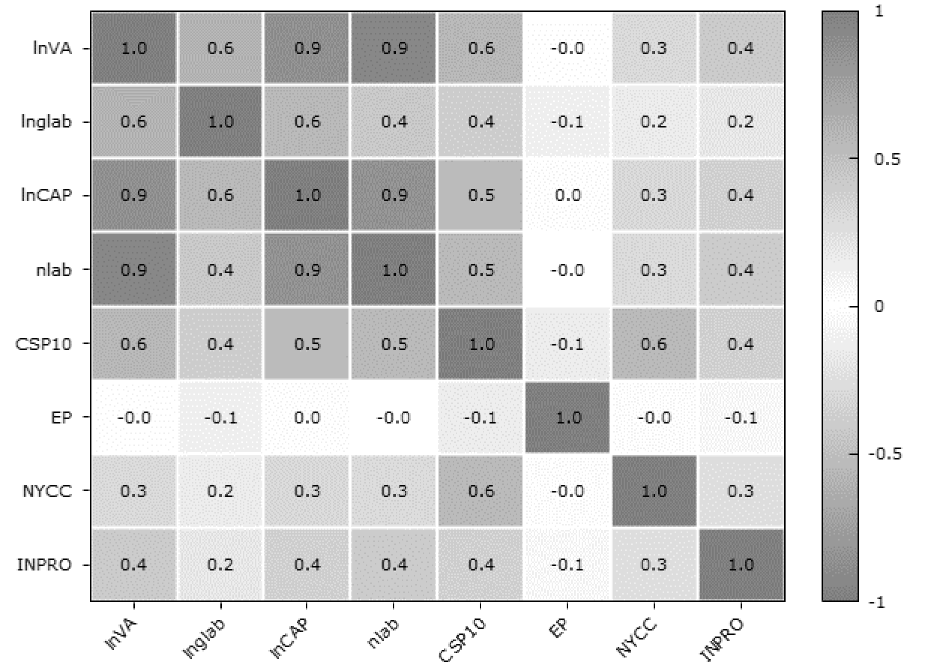
Table 5: Regression functions

Model 1	$Ln(VA_i) = \alpha + \beta_1 \cdot ln(CLAB_i) + \beta_2 \cdot ln(CAP_i) + \beta_3 \cdot ln(NLAB_i) + \beta_4 \cdot (PS_i) + \beta_5 \cdot (SQM_i) + \varepsilon_i$
Model 2	$Ln(VA_i) = \alpha + \beta_1 \cdot ln(CLAB_i) + \beta_2 \cdot ln(CAP_i) + \beta_3 \cdot ln(NLAB_i) + \beta_4 \cdot (PS_i) + \beta_5 \cdot (CPS_i) + \varepsilon_i$
Model 3	$Ln(VA_i) = \alpha + \beta_1 \cdot ln(CLAB_i) + \beta_2 \cdot ln(CAP_i) + \beta_3 \cdot ln(NLAB_i) + \beta_4 \cdot (PS_i) + \beta_5 \cdot (INPRC_i) + \varepsilon_i$

4. RESULTS

In the following figure (Figure 1: Correlation matrix) the correlation matrix of all the variables participating in the study is shown. This matrix helps in the interpretation of the results since it shows the relationship that each one of the variables has with the rest. The closer to 1 and -1 in the value of the correlation coefficient, the stronger the relationship between the variables will be.

Figure 1: Correlation matrix



All the OLS estimates made in this paper were obtained through the Stata 9.0 econometric software. Next, we will analyze the different models made:

4.1. Model 1: Standardization and quality control systems.

We will analyze in this section whether, based on the data collected by the ESEE, the performance of standardization and quality control work have an effect on the productivity of the firm. The (Table 6: Descriptive statistics and regression results, model 1) show all the data obtained in this first study. For this model, we have selected the variable added value as a dependent variable and the other five variables as independent or explanatory variables. The value (α) is the constant of the regression function.

Table 6: Descriptive statistics and regression results, model 1

	MEAN	TYPICAL DEVIATION	MINIMUM	MAXIMUM	COEFFICIENT (βi)	P-VALUE
ln(VA)	14,8278397	1,67981117	9,46962297	20,7254026	-	-
α	-	-	-	-	-0,734066	0,0500(**)
ln(CLAB)	10,4066265	0,38241129	8,99818431	12,0060151	0,983950	$1{,}43e^{-107}$(***)
ln(CAP)	15,6165291	2,03534376	7,27931884	22,179599	0,0891797	$4{,}19e^{-12}$(***)
NLAB	4,06787214	1,33669181	0	9,33873359	0,946458	0,0000(***)
PS	0,55081967	0,49757382	0	1	0,0590018	0,0215(**)
SQM	0,36983607	0,4829185	0	1	0,0605219	0,0263(**)
R^2	0,935149					

Note: The values with (*), (**), (***) indicate a level of significance of 1%, 5% and 10% respectively.

In this first model an R^2 of 0.9351 is given. It is a value very close to one which implies that the goodness of the adjustment is high and that the selected variables explain our dependent variable (the added value) very well. In this case, both the product standardization (PS) and the performance of standardization and quality control (SQM), are significant. Both with a level of significance of 5%. The coefficient of PS is 0.059 and the SQM coefficient is 0.0605. This confirms hypotheses 1 and 2 raised. This goes in the same sense as the literature found on the same subject. As previously mentioned, good quality management has a positive influence on the productivity of firms.

The firms analyzed that follow some type of guidelines when it comes to organizing production achieve improvements in their productivity. Some of the aforementioned, such as ISO 9000 norms or models of excellence, are contrasted and have a positive effect on the productivity of firms. Guided by the literature found and the results obtained, we consider our assumptions about the use of ISO standards and models of excellence confirmed.

4.2. Model 2: Production systems

In this section we will analyze whether having a more complex production system and with greater options has an effect on the productivity of the company. In the (Table 7: Descriptive statistics and regression results, model 2) all the data obtained in this study are shown. For this model, we have selected, as in the first model, the variable added value as a dependent variable and the other five variables as independent or explanatory variables. The value (α) is the constant of the regression function.

Table 7: Descriptive statistics and regression results, model 2

	MEAN	TYPICAL DEVIATION	MINIMUM	MAXIMUM	COEFFICIENT (βi)	P-VALUE
ln(VA)	14,8278397	1,67981117	9,46962297	20,7254026	-	-
α	-	-	-	-	-0,630937	0,0974(*)
ln(CLAB)	10,4066265	0,38241129	8,99818431	12,0060151	0,973181	$3{,}97e^{-104}$(***)
ln(CAP)	15,6165291	2,03534376	7,27931884	22,179599	0,0900460	$2{,}49e^{-12}$(***)
NLAB	4,06787214	1,33669181	0	9,33873359	0,941414	0,0000(***)
PS	0,55081967	0,49757382	0	1	0,0655194	0,0119(**)
CPS	2,93114754	2,41628477	0	10	0,0120417	0,0618(*)
R^2	0,935076					

Note: The values with (*), (**), (***) indicate a level of significance of 1%, 5% and 10% respectively.

In this model an R^2 of 0.9350 is given, just as before it is a value very close to one, making the goodness of the adjustment high. In this case, the product standardization (PS) continues to maintain values of significance and coefficient similar to the previous ones (5% and 0.065). In addition, we observe how the variable we have named complexity of the productive system (CPS) is equally significant, albeit weakly. This variable has a level of significance of 10% and a coefficient of 0.0618. This means that, although it explains our variable added value quite well (by 93.82%), it is not as explanatory as the product standardization. This, however, continues with the previous thread, confirming hypothesis 1 again and validating hypothesis 4.

As we have seen previously, the variable CPS is a set of variables that represent a series of flexible technologies, internal communication, etc. Valuing this together with the positive results and comparing all the previous information of the literature, they show the importance that all these technologies have for the productivity of the companies. Narasimhan et al. (2006) and Vázquez-Bustelo et al. (2007) confirm in the same way that flexible manufacturing technologies such as robotics contribute to the development of agile production.

Martínez-Sánchez et al. (2018) explain how a good organizational support is key for an agile and efficient production. The firms are developing electronic value chains, such as local area networks (LAN), where the machines of the companies are interconnected and through a server of the central office the informative data of the same are collected. All this supports in a certain way the study carried out here. So having a more sophisticated production system, where there is a good organization and a series of technological capabilities, will help firms to have a more agile production and ultimately obtain greater productivity.

The variables that make up the CPS factor have a great relationship with everything that have been analyzed throughout this paper. Nowadays, as has been said several times throughout this paper, agile production is an integrated concept within the Spanish manufacturing firms. These concepts are among others: the use of flexible systems (such as the organization in work cells); the use of robotics (which can range from robotic arms programmed in production processes, to robots dedicated to internal transport); the use of internal communication systems (such as the use of LAN networks that can range from inventory management to communication between machines; or even everything related to the technological assimilation or the realization of studies that allow to improve the designs). They are factors that mark the complexity of each productive system and that can make a competitive difference between firms. Providing advantages to those that are capable of integrating them into their productive chain. These concepts are also some of the bases used in the concept of agile production.

4.3. Model 3: Process innovation

In this last model, we analyze if making innovations in the productive process gives the company some advantage in its productivity. In the (Table 8: Descriptive statistics and regression results, model 3) all the data obtained in this study are shown. For this model we have selected, as in the previous models, the variable added value as a dependent variable and the other five variables as independent or explanatory variables. The value (α) is the constant of the regression function.

Table 8: Descriptive statistics and regression results, model 3

	MEAN	TYPICAL DEVIATION	MINIMUM	MAXIMUM	COEFFICIENT (βi)	P-VALUE
ln(VA)	14,8278397	1,67981117	9,46962297	20,7254026	-	-
α	-	-	-	-	-0,719584	0,0539(*)
ln(CLAB)	10,4066265	0,38241129	8,99818431	12,0060151	0,982439	$7{,}45e^{-108}$(***)
ln(CAP)	15,6165291	2,03534376	7,27931884	22,179599	0,0915712	$7{,}22e^{-13}$(***)
NLAB	4,06787214	1,33669181	0	9,33873359	0,935176	0,0000(***)
PS	0,55081967	0,49757382	0	1	0,0626644	0,0145(**)
INPRC	0,67422566	0,99281283	0	3	0,0513365	0,0003(***)
R^2	0,935549					

Note: The values with (*), (**), (***) indicate a level of significance of 1%, 5% and 10% respectively.

In this last analysis an R^2 of 0.9355 is given, as in the two previous models it implies a goodness of the high adjustment. In this third model, the situation of product standardization (PS) is similar, maintaining values of significance and coefficient similar to the previous ones (5% and 0.0626). In addition, we observe how the variable we have named process innovation (INPRC) is equally significant with a level of 1% and a coefficient value of 0.05133. This variable explains the independent variable very well and in this way, hypothesis 1 continues confirming and hypothesis 3 is validated, both in section 2.4. In the same way as before, it is related to what was found in the aforementioned literature. The manufacturing firm has incentives to carry out process innovations due to it achieves increases in its productivity.

4.4. General comment of the regression models

In the three models studied a series of common characteristics are fulfilled. In all three cases, the sum of the coefficients of capital (CAP) and work (NLAB) is greater than one, which implies that there are slightly increasing returns to scale. In addition, in all three models the R^2 is a high value, assuming a goodness of the high setting.

If we make a comparison of the results of the three models, we can appreciate the relationships of the three most interesting variables (SQM, CPS and INPRC) with the added value of the firms. Taking into account that these three variables are linear and that the added value is logarithmic, we can know what individual relationship each variable has.

From model 1 we obtain that for each unit of variation of SQM the natural logarithm of the added value increases by 100 * β%, that is, it would increase by 6.05%.

In the same way as with model 1, it is possible to analyze how an increase of one unit of the CPS and INPRC variables would affect the productivity of firms. In the case of CPS, the increase in the natural logarithm of added value would be 1.2% and the contribution of INPRC would increase by 5.1%.

The case of product standardization is quite similar in all three models. The coefficient that will mark the elasticity of this factor is 0.059 in the first model, 0.065 in the second, the average is therefore 0.062. This implies that by an increase of one unit of the PS factor, the natural logarithm of the added value will increase by 6.2%. This makes it the highest value of the 4 variables analyzed.

These results reflect the importance of these factors with respect to productivity. In turn, they enhance the effect on the productivity of carrying out these activities, which as are already mentioned above, the basis of agile production or lean manufacturing. We can say that organizing the production of firms based on this concept can provide them with an important competitive advantage.

4.5. Study by sectors of added value and production complexity

Here a study has been carried out with the average values by sectors of the variables: added value and the complexity of the production system (Table 9: CPS and VA averages).

Table 9: Study of CPS and VA averages

SECTOR	CPS AVERAGE		NUMBER OF FIRMS	VA AVERAGE	
1. Meat industry	2,461538462	15º	65	16105277,49	7º
2. Food products and tobacco	2,521505376	14º	186	9782182,882	11º
3. Drinks	2,909090909	9º	33	15574599,94	8º
4. Textiles and clothing	1,93	18º	100	2512965,47	18º
5. Leather and footwear	1,734693878	19º	49	1651538,816	19º
6. Wood industry	1,212765957	MÍN	47	1576536,766	MÍN
7. Paper industry	2,869565217	10º	69	8787147,812	13º
8. Graphic arts	2,368421053	16º	57	3883572,193	16º
9. Chemical industry and pharmaceutical products	3,508928571	5º	112	29676070,69	5º
10. Rubber and plastic products	3,2	7º	80	18717987,7	6º
11. Non-metallic mineral products	2,828282828	13º	99	11086553,11	10º
12. Ferrous and non-ferrous metals	3,098039216	8º	51	43770408,69	3º
13. Metallic products	2,856410256	12º	195	4499541,303	14º
14. Agricultural and industrial machines	3,989361702	4º	94	8823218,011	12º
15. Computer, electronic and optical products	4,384615385	3º	26	35206728,65	4º
16. Machinery and electrical equipment	3,290909091	6º	55	14874229,75	9º
17. Motor vehicles	4,64	2º	75	60926687,48	MÁX
18. Other transport material	4,774193548	MÁX	31	53669388,97	2º
19. Furniture industry	2,868852459	11º	61	3885526,131	15º
20. Other manufacturing industries	2,3	17º	40	2897395,325	17º
CPS minimum	1,212765957	VA minimum		1576536,766	
CPS maximum	4,774193548	VA maximum		60926687,48	

Analyzing the (Table 9: CPS study and VA averages), we can observe how the results coincide for both variables. In the case of the maximum values, it can be seen how the first two sectors (17 "Motor vehicles" and 18 "Other transport material") are those that have both the highest values for the average added value and the two referred to the complexity of the highest productive system. The same situation occurs for the lowest values, where the sectors (5 "Leather and footwear" and 6 "Wood industry") have the smallest average value of added value and the complexity of the production system.

This goes in the same line as the results obtained where the regression indicated that a greater complexity of productive system was related to a higher productivity of the firm.

5. DISCUSSION OF RESULTS AND CONCLUSIONS

As for the results of this paper, the conclusions drawn from it, are based on the review of the academic literature, the empirical analysis and the proposals for improvement in the situation of technology in Spain in 2016.

Studies using the OLS method have allowed us to verify the positive relationship between the study variables and productivity. In particular, it has been found that the variable corresponding to the use of quality management and standardization systems is the most influential of the three on which the entire paper has been based. The SQM variable obtained the highest β value (0.061) in model 1. As a result, we confirm that the implementation of quality management systems in Spanish manufacturing firms clearly improves the productivity of these.

In terms of innovation, the conclusions are quite similar to those of quality management systems. The coefficient β obtained in model 3 for process innovations (INPRC) is equally positive and 0.051. This is consistent with all the literature reviewed where it is stated that betting on innovation in firms positively affects their productivity.

Regarding the complexity of the productive system, it should be noted that the results show positive values due to the coefficient β is 0.012. Thus, a greater complexity of the production process generates a greater productivity of the manufacturing firm.

ased on all the information presented in this paper, it could be considered that it has been possible to contribute to the academic literature a new result in Spain on the importance of the use and continuous renewal of the productivity of firms, both standardization and quality management systems, as well as new technologies. In addition, we carry out a literature review about concepts related with quality management, innovation and production systems in the field of Spanish manufacturing firms.

Depending on the results and conclusions of this work, entrepreneurs, who still do not apply standardization and quality management techniques and have not a complex and modernized production system, could be encouraged to try to introduce these concepts and either through innovation or through the application of concepts such as agile production. This will allow them to use new technologies and techniques in their production processes, which will mean a change in the organization and will have a positive effect on the productivity of the firm.

In the same way that we refer to entrepreneurs, we can address those responsible for Spanish economic policy, to convey the importance for the economy of the country of betting to increase the effort in innovation and improvement of production systems of the Spanish firms. This could be done by increasing aid to firms that want to grow in these two issues. Maté García and Rodríguez Fernández (2002) note how there are weaknesses in the investment in innovation and development of Spanish firms, which can cause a loss of competitiveness of Spanish firms compared to those of other European countries.

The results and conclusions of this work open new lines of study. For example, our approach could apply in another geographical area and compare the results. In addition, the effect of the use of standardization and quality management techniques could be studied, as well as having a complex production process on the ability to absorb knowledge from competing companies, customers or suppliers.

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REFERENCES

Añaguari Yarasca, M. A.; Gisbert Soler, V. (2016). *Lean Manufacturing como herramienta de competitividad en las pymes españolas*. 3C Tecnología: glosas de innovación aplicadas a la pyme, 5(3), pp. 20-29.

Arraut Camargo, L. C. (2011) *Gestión de calidad en PYMEs manufactureras certificadas con ISO 9001-2000*. Revista del Centro de Investigación. Universidad La Salle, 9(35), pp. 79-97.

Barge-Gil, A.; López, A. (2011). *Realización de I+D y su composición en la empresa manufacturera española, análisis de los determinantes diferenciados de la investigación y el desarrollo.* Economía industrial, 382, pp. 25-34.

Becker, S. W. (1993). *TQM does work: Ten reasons why misguided attempts fail*. Management Review, USA: IMT, 82(5), pp. 99-120.

Buisán, M. y Valdés, F. (2017), L*a industria conectada 4.0.* Revista La Economía Digital en España ICE, 898, pp. 89-100.

Cuatrecasas Arbós, L.; González Babón, J. (2017). *Gestión integral de la calidad: Implantación, control y certificación*. 5th ed. Barcelona: Profit.

Demuner Flores, M. R.; Mercado Salgado, P. (2011) *Gestión de calidad en PYMEs manufactureras certificadas con ISO 9001-2000*. Revista del Centro de Investigación. Universidad La Salle, 9(35), pp. 79-97.

Dobrzykowski, D.; Leuschner, R.; Hong, P. (2015). *Examining absorptive capacity in supply chains: Linking responsive strategy and firm performance.* Journal of Supply Chain Management, 51(4), pp. 3-28.

Fisher, T. J. (1991). *The Impact of Quality Management on Productivity*. International Journal of Quality & Reliability Management, UK: Emerald, 9(3), pp. 5-14.

Frías, J. (2006). *La Tercera Edición del Manual de Oslo amplía el concepto de innovación a la de carácter no tecnológico.* Revista Economía Industrial, 360.

Giménez Espín, J. A.; Jiménez Jiménez, D. y Martínez Costa, M. (2014). *La gestión de calidad: importancia de la cultura organizativa para el desarrollo de variable intangibles.* Revista Europea de Dirección y Economía de la Empresa, 23, pp. 115-126.

Griffith, R.; Redding, S., Van Reenen, J. (2004). *Mapping the two faces of R&D: productivity growth in a panel of OECD industries.* The Review of Economics and Statistics, 86(4), pp. 883–895.

Griful Ponsati, E.; Canela Campos, M. (2005). *Gestión de la calidad.* Barcelona: Edicions UPC.

Gunasekaran, A. (1999a). *Agile Manufacturing: A Framework for Research and Development*. International Journal of Production Economics, 62(1-2), pp. 87-106.

Gunasekaran, A. (1999b): *Design and Implementation of Agile Manufacturing Systems*. International Journal of Production Economics, 62(1-2), pp. 1-6.

Gunasekaran, A.; Yusuf, Y. (2002): *Agile Manufacturing: A Taxonomy of Strategic and Technological Imperatives.* International Journal of Production Research, 40(6), pp. 1357-1385.

Hernández Matías, J. C.; Vizán Idolpe, A. (2013). *Lean Manufacturing: conceptos, técnicas e implantación.* Madrid: Escuela de Organización Industrial, Universidad Politécnica de Madrid.

Martínez Sánchez, A.; Pérez Pérez, M.; Vicente Oliva, S. (2018). *Agilidad, flexibilidad de producción e innovación en la empresa manufacturera española.* Revista de Dirección y Organización, 65, pp. 60-71.

Maté García, J. J.; Rodríguez Fernández, J. M. (2002). *Crecimiento de la productividad e innovación en I+D: Un análisis empírico de las empresas manufactureras españolas.* Economía Industrial, 1347, pp. 99-110.

Minguela-Rata, B.; Fernández-Menéndez, J.; Fossas-Olalla, M.; López-Sánchez, J. I. (2014). *Colaboración tecnológica con proveedores en la innovación de productos: análisis de la industria manufacturera española.* Innovar Journal, 24, pp. 55-65.

Narasimhan, R., Swink, M.; Kim S. (2006). *Disentangling leanness and agility: An empirical investigation.* Journal of Operations Management, 24, pp. 440-457.

Ortiz, F. (2006). *Gestión de innovación tecnológica en PYMES manufactureras.* I Congreso Iberoamericano de Ciencia, Tecnología, Sociedad e Innovación, México.

Padilla, L. (2010). *Lean manufacturing manufactura esbelta/ágil.* Universidad Rafael Landívar. Facultad de Ingeniería. Revista Ingeniería Primero, 15, enero 2010, pp.64-69.

Rahani, A. R.; Al-Ashraf, M. (2012). *Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study*. International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012). Faculty of Mechanical Engineering Universiti Teknologi MARA. Procedia Engineering, 41, pp.1727-1734.

Rosell-Martínez, J.; Sánchez-Sellero, P. (2012). *Foreign direct investment and technical progress in Spanish manufacturing*. Applied Economics, 44(19), pp. 2473–2489.

Salegna, G.; Fazel, F. (1995). *An integrative framework for developing and evaluating a TQM implementation plan*. Quality Management Journal, USA: ASQ, 3(1), pp. 73-84.

Sánchez-Sellero, P.; Rosell-Martínez, J.; García-Vázquez, J. M. (2014). *Absorptive capacity from foreign direct investment in Spanish manufacturing firms*. International Business Review, 23(2), pp. 429-439.

Sánchez Sellero, P.; Sánchez Sellero, M. C.; Sánchez Sellero, F. J.; Cruz González, M. M. (2015). *Effects of Innovation on Technical Progress in Spanish Manufacturing Firms*. Science Technology and Society, 20(1), pp. 44–59.

Vázquez Bustelo, D.; Avella Camarero, L. (2007). *Contraste empírico del modelo de fabricación ágil en España*. Información Comercial Española, 835, pp. 285-306.

Vázquez-Bustelo, D.; Avella, L.; Fernández, E. (2007), “Agility drivers, enablers and outcomes: Empirical test of an integrated agile manufacturing model”, International Journal of Operations & Production Management, 27(12), pp. 1303-1333.