The impact of using technologies in business settings

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Abstract

Modern technologies changed radically production processes. This paper explores the degree of use of different modern manufacturing technologies, shop floor technologies and information infrastructure technologies, as well as their impact on performance. Therefore, first we show the use of technologies in firms, differentiating between implementation and diffusion. Second, we test the relationship between, on the one and side, implementation and performance, and on the other hand side, diffusion and performance. The empirical evidences come from the European Manufacturing Survey 2006 Spanish edition. The descriptive results show that the most implemented technologies are CAD – shop floor technology-, followed by ERP – information infrastructure technology-, industrial robots and automated handling systems – shop floor technology-. When it comes to the different degrees of use most technologies have a low or medium diffusion. The correlation results demonstrate that there is a positive relationship between diffusion of technologies and performance rather than between implementation and performance.

Keywords: shop-floor technology, information infrastructure technology

1. Introduction

The use of different manufacturing technologies in factories is a subject to consider when analyzing the impact of innovations in enterprises. A paradigm to study is the impact of manufacturing technologies on performance.

The way in which manufacturing systems have responded to customer requirements could be analyzed from quite different perspectives. On the one hand, we could consider the traditional classification of how a factory organizes material flow (Job-shop, Batch shop, Assembly line or continuous flow) or the strategy to respond to demand (Engineer to Order; Make to Order; Assembly to Order and Make to Stock). On the other hand, a swift trend towards a multiplicity of finished products with short development and production lead times has been observed. In the meantime, it has led many companies into problems related to manufacturing such as inventories, overheads and efficiencies, among others (Sharp, 1999). Success in manufacturing, indeed even survival, has become increasingly difficult. In nowadays scenario, competition intensified from a national scale to a global arena, product life cycles shrunk, yet there is a growing requirement to satisfy customers' specific and individual needs (Jin-Hai, 2003).

Different authors' research demonstrated that there is a variety of ways companies can improve their manufacturing function in order to enhance their competitive advantage. Despite the resultant variety in manufacturing research, some clear trends are emerging. We note, for example in production systems, that rigid manufacturing systems are gradually changing into flexible manufacturing systems in order to improve the system's ability to respond to consumers' needs (Jin-Hai, 2003).

Historically, the first known philosophy is mass production and the evolution has carried other points of view to respond to that demand. In this way we consider several steps in progress of management techniques: from Inventory Management and Economic Order Quantity to Lean Management, the Theory of Constraints and Agile Manufacturing. Clearly, there appears to be many manufacturing panaceas, with much description about their philosophy.

2. Variables for measuring

However, information technologies (IT) related concepts and their impact are challenging areas of study in the framework of changing in manufacturing systems. The term IT is approached in a broad sense, and as such it refers to any artefact whose underlying technological base comprises computer or communications hardware and software. It is therefore necessary to set up effective cross-functional information systems and it should be take into account that IT requires specific attention. There are a number of enabling Information and Communication Technologies which are critical to successfully enhance the manufacturing firms' performance.

We do not enter the complex discussion on IT in manufacturing settings, but based on the previous broad definition and taking into account the present paper, we clearly distinguish between two IT related manufacturing technologies: 1) Shop floor manufacturing technologies (SFT), and 2) Information Infrastructure manufacturing technologies (IIT). The former represent the technologies on the floor at operational level and the latter refer to IT which supports the structure of processes in factory and in customer and/or supplier relationships.

Therefore, based on this classification, we differentiate between Shop floor technologies, including (1) Computer aided design (CAD); (2) Computer controlled machinery or equipment (CAM); (3) Integration of design and computer controlled machinery (CAD-CAM); (4) Industrial robots and automated handling systems (for tools or parts) and (5) Computer controlled warehouses/ material handling systems, and Information Infrastructure technologies including (1) Enterprise resource planning software (ERP) and (2) Exchange of production schedule data with other companies (Supply Chain Management). More IT could be taken into account, but we assume these are representative enough for analyzing the presence of the different technologies in manufacturing environments.

3. Objective

The contribution of the present paper is twofold. On the one hand side, firms represent the backbone of any innovation system, in which policy makers create an environment conductive to innovation, research institutions provide knowledge and science, while ultimately enterprises use technologies in order to create innovative products and processes. It is important to show the impact of modern manufacturing technologies on outcomes in order to create awareness and reasons for an advanced implementation, as well as factual proofs complementing the political discourse. Accordingly we have to ask to these final users about the use of information technologies to promote or support their use or application.

On the other hand side, our intention is to use and show the results of the European Manufacturing Survey (EMS), an international survey combining innovation, production, organizational and technological concepts. We limit our analysis to the Spanish sub-sample resulting from the 2006 survey conduction round. The survey's main purpose is to bring recent and complementary source of information to the existing surveys in the field, providing valuable information on a grate variety of topics. This complex methodology addressed to international manufacturing environments is a necessity nowadays, when important efforts are deployed in methodology standardization and systematization.

The main interest of the present paper relies on measuring the impact on profitability, measured by the return on sales, of the different manufacturing technologies above described. However the impact of different technologies could be significantly different among studied manufacturing sectors. Although aware on some limitations of the OECD's (2003) classification of manufacturing industries based on technology into High-technology industries (HT), Medium-high-technology industries (MHT), Medium-low-technology industries (MLT) and Low-technology industries (LT) we use this taxonomy in order to test the different characteristics of the proposed manufacturing technologies and their relation to performance.

First, we analyze the implementation and diffusion of the seven selected manufacturing technologies in the different economic activity sectors in Spain. Second, we show the possible relationship between the selected variables and factory performance, measured by return on sales.

The results presented in the present paper correspond to a first exploitation of the Spanish dataset. Further analysis targets larger sample populations resulting in international comparisons as well as the inclusion of other technologies (up to thirteen) and organizational concept in manufacturing settings.

4. Methodology

This contribution is based on the Spanish sub-sample of a European manufacturing survey described briefly in the followings. The European Manufacturing Survey (EMS), coordinated by the *Fraunhofer Institute for Systems and Innovation Research - ISI*, collects detailed information on innovations in manufacturing. The main objectives of this research project are to find out more on:

– the use of production and information technologies

– new organisational approaches in manufacturing

– the best management practices' implementation

In the last (2006) edition EMS has been carried out in 12 countries (Austria, Croatia, France, Germany, Greece, Netherlands, Slovenia, Spain, Switzerland, Turkey, United Kingdom and Italy) resulting in approximately 3.500 responses.

The European Manufacturing Survey tries to contribute towards the standardization of use of information on organizational and technological concepts. In last years, different surveys have been launched with the aim of measuring the use of new technological and organizational concepts. The great disparity of methodologies used until now resulted into a low degree of comparability among the data collected. EMS is not intended to be "new" or "better", it rather proposes a complex methodology as a first step towards a common way for collecting information on technological and organizational concepts among others.

4.1. Complexity of organisational innovations (aggregation level)

The term organisational innovation may include many different concepts of how to change traditional organisational structures. Organisational innovations can affect business processes (e.g. continuous improvement processes) as well as organisational structures (e.g. team work).

Organisational innovations may occur in an enterprise itself (intra-organisational perspective, e.g. simultaneous engineering), but may also concern relationships with other companies (inter-organisational perspective, e.g. R&D cooperation).

For this reason the EMS's questionnaire asks for the use of –up to 13- technologies and organizational concepts, not limiting the question to the general use of those concepts in the firm in the last 3 years. For this reason, technological and organizational concepts are listed in two different blocks. For every concept, information on implementation (yes/no), degree of implementation (low/medium/high), first year of use, motives for non-use and willingness in future implementation is collected.

An in-depth analysis with single organizational innovations instead of an overall indicator should help to detect which organizational concepts are positively correlated with a better performance in terms of productivity while others had no significant influence.

4.2. Scope of organizational innovations (use or extent of use)

The treatment of the organisational innovations versus product/process innovations should be differentiated. The measure of success of a firm developing new products consist in knowing the number of new products launched, among all product designed, into the market.

However, this fact does not occur in the firms which use new organizational concepts in the firm. The impact of its use is no clear into the results in terms of productivity. There are no clear quantitative indicators which show, in term of results, the impact of the use of an organisational innovation. For this reason and with the aim of knowing their impact on results, EMS considers necessary capturing the extent of their use (low, medium or high).

However, these are general features of the EMS "philosophy". A set of core questions is common for all countries, while a set of country-specific questions refer to each country's specific reality and issues related to the current situation object of research are considered.

For the purpose of the present paper, a sample of Spanish firms was determined by the manufacturing establishments (NACE code 15-37) having at least 20 employees. The Spanish National Statistic Institute facilitated the distribution of all manufacturing establishments having these characteristics. Approximately, 10% of the population received the EMS questionnaire, corresponding to 4.450 surveys.

The questionnaires were sent out by postal mail to the selected firms in two rounds. The first round was sent out in April 2006 while the second one was in June 2006. Besides the common core questions included in the questionnaires of the twelve countries, the Spanish questionnaire contains three additional questions thematically related to safety culture, family business and team work organization.

Our final dataset consists of 151 entries. With the 4.450 questionnaires sent out this represents a response rate approximately of 3.5%. In our view, such a low response rate is due to this being the first run of the survey and the non-obligatory character of participation compared to other mandatory surveys such as the Community Innovation Survey.

The returned questionnaires show that the majority of enterprises belong to the lowest technology intensity industries. There are only four high technology intensity firms in the sample. Analyzing the R&D expenditure by technology intensity there is coherence in means, higher technological intensity the higher the R&D expenditure. On the other hand, the machinery and equipment investment is higher as lower is the intensity. Table 1 is a summary of descriptive features of the companies classified by the OECD taxonomy.

Table 1. Summary of descriptive features of the sample by OECD technology intensity (means)

	LT	MLT	MHT	HT	Total
R&D expenditure as % of turnover	1,55%	2,46%	2,86%	7,75%	2,54%
Machinery and equipment investments (M€)	24,16	1,39	1,65	0,54	8,90
Total sales turnover (M€)	54,16	196,61	56,53	10,95	96,49
Year founding	1967	1957	1954	1983	1960
Total number of employees	252	111	220	96	194

5. Results

As presented in the methodology section, EMS allows complex responses and lots of details for each concept in part. Apart from the yes/no response for the use/implementation of a technology (Table 2), we consider the degree of use (high, medium or low) (Table 3) and the year of implantation (Table 4). We show these results in relation to the classification of manufacturing industries based on technology (OCDE).

5.1. Implementation of technologies

The data contained in Table 2 shows at least two facts that have influence on the following analysis:

– There are two variables that show high levels of NO responses, more concretely in the case of two technologies - *Computer controlled warehouses/ material handling systems* and *Exchange of production schedule with other companies* - the share of negative answers exceeds 85%. Due to the objective of the present paper of relating implementation and diffusion to results, we think that the elevate number of negative responses is a grounded reason to exclude the technologies from the present analysis. In the meantime, as a preliminary conclusion the data shows that the implementation of *Computer controlled warehouses/ material handling systems* and *Exchange of production schedule with other companies* is scarce among the surveyed firms.

– Another issue concerns the relationship between the selected technologies and the OCDE classification. In all cases, indifferently from the technology, the share of affirmative responses increases with the technological intensity, meaning that the implementation increases with technological intensity. Unfortunately, the group of High-technology industries contains 4 cases. Therefore, in the next sections medium-high technologies are merged with high-technology industries forming the group Medium-high technology and high technologies (MHT-HT).

Table 2. Implementation/use of technologies

			Classification of manufacturing industries based on technology (OCDE)					
			LT	MLT	MHT	HT	Total	%
SFT	Computer aided design (CAD)	No	24	8	9	0	41	27%
		Yes	24	38	43	4	109	73%
	Computer controlled machinery or equipment (CAM)	No	25	26	28	0	79	53%
		Yes	22	20	23	4	69	47%
	Integration of design and computer controlled machinery (CAD-CAM)	No	35	30	32	1	98	66%
		Yes	13	16	18	3	50	34%
	Industrial robots and automated handling systems (for tools or parts)	No	29	17	25	0	71	48%
		Yes	19	29	26	4	78	52%
	Computer controlled warehouses/ material handling systems	No	42	41	43	3	129	87%
		Yes	6	4	8	1	19	13%
IIT	Enterprise resource planning (ERP) software	No	23	16	20	1	60	41%
		Yes	24	27	31	3	85	59%
	Exchange of prod. schedule with other companies (supply chain management)	No	45	40	37	4	126	85%
		Yes	3	5	14	0	22	15%

In conclusion, we separate from the analysis two variables. On the one hand, *Computer controlled warehouses/material handling systems* is a technology not very extended in Spain. From commercial point of view, there is a clear gap between the possible advantages of this technology and its real use among the respondent firms. Therefore, either there could be a sales opportunity for firms/providers/suppliers dealing with this kind of products or perhaps *Computer controlled warehouses/material handling systems* it is not a core competence of manufacturing firms. In fact, it is quite common to find firms that outsource their warehouse management and handling operations. On the other hand, *Exchange of production schedule with other companies (SCM)* is a technology which, from our point of view, is not very implemented in firms in Spain.

5.2. Degree of implementation

Considering these exploratory results and the previous considerations, Table 3 includes the degrees of use in the selected technologies. According to this, Information Infrastructure is associated to a unique technology, namely ERP systems.

Table 3. Degree of use of technologies

			Classification of manufacturing industries based on technology (OCDE)				
			LT	MLT	MHT-HT	Total	%
SFT	Computer aided design (CAD)	High	3	3	2	8	8%
		Medium	14	11	14	39	38%
		Low	6	21	30	57	55%
	Computer controlled machinery or equipment (CAM)	High	0	2	3	5	8%
		Medium	12	6	12	30	47%
		Low	8	9	12	29	45%
	Integration of design and computer controlled machinery (CAD-CAM)	High	5	3	4	12	25%
		Medium	4	3	6	13	27%
		Low	4	9	10	23	48%
	Industrial robots and automated handling systems (for tools or parts)	High	2	1	3	6	8%
		Medium	3	10	11	24	34%
		Low	11	14	16	41	58%
IIT	Enterprise resource planning (ERP) software	High	2	2	6	10	13%
		Medium	6	10	6	22	29%
		Low	10	13	21	44	58%

The information in Table 3 shows the technologies having high degrees of implementation: the *Integration of design and computer controlled machinery* (CAD-CAM) followed by *Enterprise resource planning (ERP) software* with 25% and 13% shares of responses for high implementation. Among highest shares of medium degree implementation the technologies that stand out are: *Computer controlled machinery or equipment* (CAM)(47%), *Computer aided design* (CAD) (38%) and *Industrial robots and automated handling systems (for tools or parts)* (34%).

5.3. Year of implementation

As no previous official data on manufacturing technologies' first use is available in Spain, we opt for showing the year of introduction of the selected technologies. Among the Shop Floor Technologies, the chronological sequence is the following (from earliest to latest): Computer aided design (CAD), Industrial robots and automated handling systems (for tools or parts), Computer controlled machinery or equipment (CAM), Integration of design and computer controlled machinery (CAD-CAM). Information Infrastructure technologies are the most recent with average year of introduction of 1997.

Table 4. Year of first use of technologies

	N	Min	Max	Mean	SD
Computer aided design (CAD)	99	1980	2004	1995,0	4,654
Computer controlled machinery or equipment (CAM)	58	1980	2005	1995,8	6,050
Integration of design and computer controlled machinery (CAD-CAM)	43	1980	2006	1996,4	5,933
Industrial robots and automated handling systems (for tools or parts)	66	1970	2006	1995,2	8,171
Enterprise resource planning (ERP) software	72	1980	2006	1997,1	6,127

5.4. Technologies effect on results

For measuring technologies' effects on results we computed two new variables:

- SUMTEC – sum of technologies used; it takes values from 0 to 5 meaning that firms have responded affirmatively on the implementation of the selected technologies, 0 meaning that none of the technologies selected by the authors are implemented in the firm, and 5 that all selected technologies are used in the firm

- SUMHIGH – sum of technologies having a high degree of implementation; it takes values from 0 to 5, 0 meaning that none of the selected technologies has a high implementation and 5 that all technologies are highly implemented in the firm

Our purpose in this section is to show through bivariate correlations that it is not the sum of technologies that has a positive effect on return on sales; it is rather the degree of implementation that correlates positively with the result variable while no clear relationship is detected between technological intensity and results in terms of return on sales (Table 5).

Table 5. Technological intensity and return on sales (2005)

	Classification of manufacturing industries based on technology (OCDE)			
	LT	MLT	MHT and HT	Total
Negative	5	3	5	13
Up to 2%	11	2	7	20
2 to 5%	9	11	10	30
5 to 10%	6	10	9	25
Over 10%	5	5	4	14
N	36	31	35	102
$\chi 2$: 7,855				

The Chi-square tests in Table 6 and Table 7 test the independency between the variable referring to the sum of technologies used and the sum of highly implemented technologies and the variable indicating companies' on sales. The significance level of the correlation indicates that we can reject the null hypothesis (independency between two variables) in the case of the variable indicating the sum of technologies having high implementation and results.

Table 6. Sum of technologies used and return on sales (2005)

	Sum of technologies used						Total
	0	1	2	3	4	5	
Negative	3	2	3	2	0	3	13
Up to 2%	3	3	0	5	5	3	19
2 to 5%	2	4	4	10	0	8	28
5 to 10%	0	5	9	4	5	2	25
Over 10%	1	1	4	4	1	3	14
N	9	15	20	25	11	19	99
$\chi2$: 31,419							

Table 7. Sum of highly implemented technologies and return on sales (2005)

	Sum of technologies used						Total
	0	1	2	3	4	5	
Negative	2	6	0	1	0	0	9
Up to 2%	4	8	2	1	0	1	16
2 to 5%	9	8	4	2	2	0	25
5 to 10%	6	8	4	2	2	1	23
Over 10%	1	2	4	3	0	2	12
Total	22	32	14	9	4	4	85
$\chi2$: 21,825 * * Significant at $p< 0.05$							

6. Conclusion

In conclusion, our primary aim was to show the use of some technologies in a sample of Spanish manufacturing firms. There are different aspects related to the term use. It includes implementation, degree of implementation and year of implementation. Then, we relate the use of different technologies with firm results, using a complex and thematically focused methodology on production.

Empirical findings show that among the Shop Floor technologies *Computer aided design* (CAD) and *Industrial robots and automated handling systems (for tools or parts)* are the technologies that are most frequent in implementation among the companies.

Among the studied Information Infrastructure technologies, one shows similar figures with those relative to shop floor, almost 60% implemented *Enterprise resource planning (ERP) software*, while only 15% of the studied companies implemented *Exchange of prod. schedule with other companies (supply chain management)*.

Our results also show that the implementation year varies among technologies, but in the case of the studied manufacturing enterprises it dates back to the middle of the '90s.

Relating the concepts of implementation versus diffusion with the company results in terms of return on sales, our result show a positive relationship between the high degree implementation (low, medium, high) and performance rather than mere implementation (yes/no).

Finally, a brief comment should be made on some of the implications. Our conclusions might target policy-makers, practitioners and those in charge with the design of survey methodologies. Still, they should not go further than recommendations.

Most often the implementation of a technology can help when willing to characterize a manufacturing sector. Still, companies most often are looking for immediate results and technologies helping them in improving their competitiveness, innovative capacity and incomes. Therefore, they should be aware that the different implementation degrees might have an effect on their performance. Last, frequently innovation and manufacturing surveys gather information on implementation with no option on the different diffusion degrees.

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