

Perceived performance effects of ICT in manufacturing SMEs

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Abstract

Purpose. We aim to investigate whether ICT resources, including investment and use of specific types of ICT as well as innovative work practices, have a positive impact on several dimensions of firm performance, taking into account both direct and indirect effects and both short and long-term effects.

Design/methodology/approach. An empirical study using data from a sample of 267 Spanish manufacturing SMEs was conducted. We have used path analysis to study direct and indirect ICT impacts. OLS regression is the estimation method employed.

Findings. Our findings show a positive relationship between ICT adoption and all the measures of perceived performance analyzed, although the impact is not always immediate since the lag effects and length differ according to the type of ICT. Managers' perceptions of ICT impact are related to the adoption of new work practices but the effects also depend positively on the number of years since new work practices were implemented. ICT impact on final performance (market share and profits and margin) takes place mainly indirectly through the improvement of internal and external communication as well as through operational performance.

Originality/value. This research extends the scope of the analysis of ICT payoff literature by analyzing direct and indirect effects and by focusing on a broad range of technologies, a variety of performance measures and several time lags to study ICT adoption impacts in SMEs.

Research limitations/implications. The main limitations of the research stem from the specific geographical context under consideration and restrictions relating to the cross-sectional nature of the data.

Practical implications. Our results reveal the wide scope of the benefits of ICT adoption in SMEs and point to the need for persistence in use so as to obtain good results in some areas. They also stress the positive effects of adopting ICTs together with organizational innovation.

1. Introduction

Evaluating Information and Communication Technologies (ICT) investment payoff constitutes a key concern for companies in managing their ICT resources. Companies are compelled to find ways to evaluate the specific impact of different types of ICT on the several dimensions of their performance.

ICT payoff becomes a crucial issue, particularly in the case of Small and Medium-size Enterprises (SMEs). SMEs may differ from larger firms in the way they address ICT adoption (Lucchetti and Sterlacchini, 2004; Haug *et al.*, 2011). However, the majority of papers on ICT effects relate to large firms and the evidence is far from conclusive.

What appears to be generally lacking from the literature on ICT payoff in SMEs are studies exploring how different types of ICT adopted by SMEs impact on different areas of performance. Studies have shown that ICT effects vary according to the type of technology being used and its degree of adoption (Lucchetti and Sterlacchini, 2004; Nevo *et al.*, 2010; Boothy *et al.*, 2010). In addition, many analyses of ICT impact on firm performance have demonstrated the existence of complementarities between technological and organizational changes (Brynjolfsson and Hitt, 2000; Boothy *et al.*, 2010; Cao, 2010; Cozzarin and Percival, 2010).

The lack of unambiguous evidence has also prompted researchers to analyze the effects on business processes as well as the effects on the organization as a whole (Dedrick *et al.*, 2003; Melville *et al.*, 2004; Liang *et al.*, 2010). Many authors have suggested that one of the reasons for inconsistent findings about ICT payoffs might be the existence of lag effects since ICT payoff may require time to materialize. However, most of the studies that take time lags into account relate to large organizations (Brynjolfsson and Hitt, 2000; Brynjolfsson *et al.*, 2002; Devaraj and Kohli, 2003; Lee and Kim, 2006; Nevo *et al.*, 2010) or specific sectors (Das *et al.*, 2011).

Our research contributes to the debate about whether ICT creates value for SMEs performance, providing empirical evidence of the relationships between information technologies, organizational innovation and firm performance from a sample of 267 Spanish manufacturing SMEs. We aim to investigate whether ICT resources, including investment and use of specific types of ICT, along with innovative work practices, correlate positively with several dimensions of firm performance, taking into account both direct and indirect effects and both short (less than 1 year of ICT implementation) and long-term effects (more than 5 years).

The present research extends the scope of the analysis of the prior literature by focusing on a broad range of technologies, a variety of performance measures and several time lags to study ICT adoption impacts in SMEs. In addition, we have analyzed ICT effects using perceptual measures (Vehovar, 2007; Tallon and Kraemer, 2007; San-Jose *et al.*, 2009) to complement the results obtained in previous quantitative analyses.

The paper is organized as follows. An overview of the relevant literature regarding ICT impact on firm performance is provided in section two. The conceptual framework and research hypotheses are presented in section three; data and methodology are outlined in section four. Section five comprises the main results of our study. The final section presents the main conclusions and discusses issues for further research.

2. Literature review

2.1. Theoretical framework

Researchers have drawn on a variety of theoretical perspectives to explain the wide range of ICT impacts on business processes and on the organization as a whole. The economic theory of production and the resource-based view (RBV) have been the most common approaches used. In many cases, findings have been ambiguous and inconclusive (Dedrick *et al.*, 2003; Melville *et al.*, 2004; Liang *et al.*, 2010).

Within the framework of the “productivity paradox” debate and using production theory as the most frequent theoretical foundation, many studies have focused on providing empirical evidence of the impact of ICT investment – mostly computers – on productivity growth and performance at the firm level.

However, the findings have been mixed and this approach has been criticized for making unrealistic assumptions and because of the form of the production function employed, among other reasons (Sircar and Choi, 2009; Nevo et al., 2010).

According to the resource-based view (RBV) firm performance is based on its specific resources and capabilities, which are difficult to imitate and create a sustained competitive advantage. Differences in ICT resource endowment, such as higher investments in ICT and their combination by firms, may enhance organizational capabilities (human resources skills, experience and other intangible capabilities) and eventually lead to superior firm performance (Bharadwaj, 2000). The findings have also been mixed, especially those analyzing ICT impact on financial performance (Dedrick et al., 2003; Melville *et al.*, 2004; Lee and Kim, 2006; Liang *et al.*, 2010).

The complementarities perspective (Milgrom and Roberts, 1990) highlights the fact that ICT investment and use are necessary but not sufficient conditions for improving performance. The existence of complementarities across firm resources can increase their joint impact on business value because it is more difficult for competitors to imitate the total effect (Melville *et al.*, 2004; Liang *et al.*, 2010). Many studies have explored the existence of complementarities between technological and organizational changes in analyzing ICT impact on firm performance (Brynjolfsson and Hitt, 2000; Brynjolfsson *et al.*, 2002; Boothy *et al.*, 2010; Cao, 2010; Cozzarin and Percival 2010).

Prior research has demonstrated that the level of ICT use by both employees and managers, as well as the skills and abilities of human capital, rather than ICT investment,

strengthens the ICT effect: the greater the use of these technologies among employees, the higher the impact on labour productivity (Black and Lynch, 2001; Boothby *et al.*, 2010; Cozzarin and Percival, 2010).

In addition, the type of technology is a significant factor in any account of ICT impact (Lucchetti and Sterlacchini, 2004). Different technologies may demand, for example, different IT skills to be implemented by the firm.

2.2. Direct and indirect effects of ICT on firm performance

Irrespective of theoretical approach, the ICT literature distinguishes between several types of performance measures: financial performance, operational performance measures and other impacts (Liang *et al.*, 2010). In turn, such ICT payoffs may be the result of the direct and indirect effects of ICT.

The final links between ICT and financial performance (using accounting measures, such as return on assets (ROA), return on equity (ROE)) comprises the vast majority of the available literature. However, evidence of these links has been far from conclusive (Dehning and Richardson 2002; Melville *et al.*, 2004). Impact on the organization as a whole has frequently been measured using variables representing market performance, such as market share and market value of the firm, among others (Dehning and Richardson 2002; Dedrick *et al.*, 2003; Liang *et al.*, 2010).

The impact on operational performance has been studied mainly using productivity measures and cost reduction (Bharadwaj, 2000; Liang *et al.*, 2010; Das *et al.*, 2011). ICT increases productivity and operational efficiency in specific business processes, not only by reducing costs but also by impacting on intangible assets such as quality improvement in design processes or life-cycle enhancement in inventory management systems (Brynjolfsson *et al.*, 2002; Devaraj and Kohli, 2003; Melville *et al.*, 2004).

ICT also enhances coordination of activities by improving information systems and internal and external communication (Brynjolfsson and Hitt, 2000; Brynjolfsson *et al.*, 2002). These technologies enable a more efficient use of information between workers and management and increased interaction among employees.

The lack of evidence of an unambiguous direct relationship between ICT and firm performance has led researchers to study indirect ICT effects. According to the process-oriented models approach (Barua *et al.*, 1995) the final impact of ICT should be measured using both intermediate variables, showing ICT effect on the business processes, and final variables, representing ICT effect on performance variables. Evidence from intermediate variables has been less abundant; however, it seems more conclusive than that obtained from the analysis of financial performance using accounting measures (Dehning and Richardson 2002; Melville *et al.*, 2004; Liang *et al.*, 2010). The effects of ICT investment on business processes have been studied using intermediate variables, such as inventory turnover, productivity, customer satisfaction, quality, flexibility and speed in product delivery (Dehning and Richardson, 2002; Dedrick *et al.*, 2003; Liang *et al.*, 2010).

2.3. Types of ICT

ICT impact also varies according to the type of technology used and its degree of adoption (Boothby *et al.*, 2010; Das *et al.*, 2011). Many studies in OECD countries confirm a higher rate of productivity growth in firms using more advanced communication technologies and in those combining and integrating several forms of technology in the various stages of the production process (Boothby *et al.*, 2010).

Given their special characteristics, network technologies (in particular, communication and ICT systems) appear to have a positive effect on firm performance, partly because they help to generate spillover effects and to extend ICT impact. Local and wide area networks and

inter-company computer networks have been positively associated with efficiency gains in internal and external communication and with higher productivity levels. These positive effects have been confirmed in practically all OECD countries (OECD, 2004).

However, such research has usually focused on one single technology, mainly personal computers, software and communications equipment, while network technologies have been, in general, less studied (Nevo *et al.*, 2010; Boothy *et al.*, 2010).

2.4. Time lags and ICT

ICT payoff may require time to materialize. Firms need time to learn, adjust or reorganize themselves, taking on board the changes effected by ICT. Several short and long-term effects may be discerned during this period of adjustment. However, there is no consensus on the timing of the impact on performance due to a specific ICT investment. Results vary markedly depending on several factors, such as the type of technology (Das *et al.*, 2011), the existence of complementary organizational innovation (Schwarz *et al.*, 2010), and ICT investment level (Nevo *et al.*, 2010).

Since the mid-1990s researchers have taken into consideration the past investment effect on firm performance by including time-lagged effects in their models, showing that such impact does not occur in a once-off way but as a continuous phenomenon. For example, Brynjolfsson and Hitt (2000) demonstrate that ICT investments have a different impact from the first year up to the sixth year and that the effect is much greater over long periods. Das *et al.* (2011) examine the effect of several types of ICT investments for a one to six-year period in the healthcare sector. Their findings show that such impacts depend on the type of technology, the performance indicator considered and the period of time after ICT investments.

To sum up, the available evidence regarding ICT impact on firm performance is inconclusive and is related mainly to large firms. The research literature has shown the need to study ICT impacts on several performance measures, final and intermediate, considering different types of ICT, complementarities between technological and organizational innovations, as well as the time-lag of their effects.

3. Research model and hypotheses

The research model proposed is designed to explore whether by investing in different types of information and communication technologies (General-use, Communication and Market-oriented ICT), their use by human resources and complementarities between ICT and organizational innovations, SMEs develop a set of ICT resources that creates value for the firm.

Firstly, ICT resources impact on communication improvement, which includes internal and external communication and coordination of activities. ICT enables a faster and more efficient use of information both within the firm and with external agents, such as customers and suppliers. ICT facilitates interaction and better coordination among workers, departments and firms.

Secondly, external and internal communication as well as coordination are expected to lead to better operational performance. Operational goals of manufacturing firms can be classified in four big areas: cost, quality, delivery and flexibility (Ahmad and Schroeder, 2003). Better communication and coordination derived from ICT adoption can help firms to better performance in these four dimensions. Increased flow of information improves decision-making processes and allows better resource allocation resulting in higher productivity and efficiency and, therefore, cost reduction. Continuous improvement in processes leading to higher quality also benefit from communication improvements by

facilitating the exchange of cross-functional ideas and the dissemination of new methods and procedures throughout the whole company (Ahn and Matsui, 2011). Better communication and coordination also improve speed and punctuality in deliveries. Information-enabled collaboration enhances customer service throughout the supply chain (Fawcett et al., 2007). With regard to flexibility, better communication with external agents such as customers, help firms to earlier detect environmental changes and respond quickly to changing competitive rules launching new products that satisfy their new needs.

Thirdly, operational performance has a straightforward effect on overall performance measures, such as market share and profits (Paul and Anantharaman, 2003; Dehning and Richardson, 2002; Dedrick et al., 2003). Good performance at the four operational performance dimensions improves customer retention and attraction and, therefore, involves increased turnover and market share. In addition, higher prices due to better product and service quality, coupled with cost reduction, increase sales margin. As a consequence, firm profits increases in two of their main constituents (turnover and margin) through better operational performance.

The hypotheses to be tested are the following:

H1. ICT resources are positively associated with firm performance

H1.a. ICT resources are positively associated with communication improvement

H1b. ICT resources are positively associated with operational performance

H1c. ICT resources are positively associated with final performance

H2. Indirect effects are more important than direct effects in explaining ICT impact on operational and final performance

H2a. ICT resources are positively associated with operational performance, mainly through communication improvement

H2b. ICT resources are positively and indirectly associated with final performance mainly through communication improvement and operational performance

H3. ICT impacts on firm performance are positively associated with organizational innovations

H4. ICT has a short-term impact on firm performance (immediate effects)

H5. ICT has a long-term impact on firm performance

H6. The long-term impact of ICT on firm performance is larger than the short-term impact.

4. Data and Methodology

The hypotheses presented above are tested with cross-sectional data from a sample of Spanish manufacturing SMEs. For the purpose of this study, we have followed the generally accepted definition of SME, that is, plants with less than 250 workers. 99% of all Spanish manufacturing firms are of this type, comprising 72% of total Spanish industrial employment (INE, 2007). The firms were located in Navarra, one of the most dynamic regions in Spain in terms of technological and economic development. Data were collected in October and November 2004. Face-to-face interviews were carried out with an executive manager in each company; in most cases, the interviewee was the managing director of the plant.

Information was obtained from 267 manufacturing SMEs. The response rate was 39.77%. In the case of Spain, due to the still limited collaboration between the manufacturing sector and university research, this rate may be considered reasonable, since it is higher than that obtained in other studies on Spanish firms (see Camelo *et al.*, 2004). In other surveys of ICT adoption, the response rate has been around 10-16% for SMEs (Daniel, Wilson and Myers, 2002; Lohrke *et al.*, 2006).

4.1. Performance Measures

Most studies of ICT payoff rely on quantitative data, although researchers in all management areas have highlighted the need to consider both quantitative and qualitative measures to assess them properly (Brynjolfsson, 1993; Ketokivi and Schroeder, 2004).

The literature has shown that perceptual data may be a suitable complement to results obtained from quantitative sources. In fact, perceptual measures have been widely used to assess ICT impacts on firm performance (Ketokivi and Schroeder, 2004; Vehovar 2007; San-Jose *et al.*, 2009; Campo *et al.*, 2011).

It has been claimed that reliance on qualitative and subjective measures might lead to biased results. However, management literature in general, and ICT impact research in particular, has found that perceptual measures correlate with the actual results (Tallon *et al.*, 1998, 2000; Ketokivi and Schroeder, 2004) and that manager perceptions are sufficiently unbiased to constitute an adequate approach to assessing ICT effects (Tallon *et al.*, 2000). This explains the argument made in the ICT literature with regard to the significance of including manager perceptions in evaluating ICT effects (Tallon and Kraemer, 2007; Vehovar, 2007; San-Jose *et al.*, 2009). Several reasons justify why executives' perceptions of ICT effect are accurate and credible in measuring impact on firm performance (Tallon and Kraemer, 2007; Vehovar, 2007).

Firstly, given their position within the company, managers play a key role in implementing ICT investment and use and become a key source of information on ICT impact. They have access to reliable information about ICT effects in all the company's domains. Besides, they employ these technologies and receive feedback about them from the firm's employees (Tallon *et al.*, 2000; Natek and Lesjak, 2005). In fact, directly asking interviewees is the most direct approach to testing the effect of innovation implementation (Godard, 2001).

Secondly, it is worth noting that it is not always feasible to obtain objective measures of ICT impact (Tallon *et al.*, 2000). The use of subjective measures allows researchers to identify the degree of achievement of more specific goals associated with ICT, such as those related to the improvement of coordination and communication activities. The use of perceptual measures enables a more in-depth account of ICT business value (Tallon and Kraemer, 2007; Vehovar, 2007).

Finally, some methodological advantages of using manager perceptions may also be highlighted. Executive assessment of ICT effectiveness allows researchers to test a moderating effect rather than relying on the interaction terms in the estimated models (Godard, 2001). When the measures used for performance do not refer specifically to the impact of the innovation, the introduction of interaction multiplicative terms can lead to collinearity problems and, if the number of interaction terms is high, to a significant reduction in the number of degrees of freedom. This problem is resolved if the dependent variables are evaluations of the innovations' effectiveness. In this case, testing the moderating effect is carried out by interpreting the coefficients of the individual independent variables.

Managers were asked to assess on a scale of zero (no effect) to ten (very significant effect) to what extent they considered that ICT use had allowed the company to reach various performance-related goals. As mentioned above, we study communication improvement, operational performance and final performance measures. Formative indexes have been used to measure performance at the three levels. Communication improvement has been measured considering two items: external communication (with other firms, public administration, etc.) and coordination improvement, as well as internal communication. The operational performance indicator has been created by including productivity growth, cost reduction, new products development, services and processes, quality improvement in products and services, and increased speed in product delivery. Finally, the final performance variable includes

margin and profits and increased market share. Table 1 shows their means and standard deviation of the original items.

INSERT TABLE 1

4.2. ICT variables

The questionnaire included questions on the various types of ICT employed by workers. Partially following the taxonomy developed by Lucchetti and Sterlacchini (2004), the ICTs have been grouped into three different categories: General-use ICT, Communication-integrating ICT and Market-oriented ICT.

General-use ICT includes Internet access and computers. Both technologies are characterized by a very high rate of adoption among firms and by generally widespread use within firms. Computers and the Internet are commonly used within firms in different business processes such as those related to production, communication and design.

Communication-integrating ICT includes email, intranet and extranet. These technologies are specifically designed to improve the communication system, either by helping to integrate several internal functions and processes or by enhancing communication among different firms and collaboration amongst work-teams through established networks of firms. Consequently, Communication-integrating ICT tools may significantly enhance the efficiency, quality and timeliness of group decision processes (Bajwa *et al.*, 2005).

Finally, market-oriented ICT includes web pages and e-commerce. These technologies are clearly oriented to the market. On the one hand, this group is identified by the existence of a firm website. According to Lucchetti and Sterlacchini (2004), websites are mainly used to improve firm visibility and to provide detailed information about products and services, as well as about the company itself. For example, firms may use websites to advertise products and to show post-product specifications (Daniel *et al.*, 2002). Additionally, information has been included here on whether the firm is engaged in e-commerce, either buying or selling

goods or services. By employing these technologies, for example, SMEs can circumvent traditional market distributors and intermediaries and communicate directly with the customer, a process known as disintermediation (Lohrke *et al.*, 2006).

To study ICT adoption by SMEs as well as time-lag effects on firm performance, the questionnaire included information on how long each of these technologies had been implemented within the company. The time periods considered were as follows: less than 1 year, between 1 and 2 years, between 3 and 5 years, and 6 years or more. Table 2 shows the length of implementation of ICT within SMEs as well as their distribution across the time-periods cited. To study whether ICT impacts differ in the short and long-term, less than 1 year is defined as short-term impact (immediate), between 1 and 5 years is defined as medium-term impact, and more than 5 years is defined as long-term impact.

INSERT TABLE 2

Along with these indicators of ICT implementation, information about a set of variables regarding ICT resources is given, such as the intensity of ICT use and the availability of ICT infrastructures. With regard to General-use ICT, information on the percentage of workers using computers, the percentage of workers using the Internet, and the number of computers per employee, as well as the percentage of total expenditure on ICT (wages, hardware, etc.), is provided. For Communication-integrating ICT, the variables considered are the percentage of workers using email and the percentage of workers using intranet or extranet. Finally, with respect to Market-oriented ICT, variables such as the percentage of sales/purchases via electronic commerce out of the total of sales/purchases have been included. Table 3 shows descriptive statistics for these quantitative indicators.

INSERT TABLE 3

A new general index was created using these variables, defined as the mean of the standardised values mentioned above. It shows the intensity of ICT implementation within the

company (Nevo *et al.*, 2010). In the same vein, we generated indices showing the intensity of implementation of each of the three groups of ICT.

Organizational innovation. To study complementarities between ICT and organizational innovations (in particular, the existence of innovative work practices), we have considered two of the most emblematic work practices in the literature on organizational change (Osterman, 1994; Handel and Gittleman, 2004): problem-solving groups and work teams.

As for ICT, to analyze innovative work practices, we have included variables reflecting their implementation: years of implementation in the company and intensity of use. With regard to the former, five variables have been created, indicating which of the two cited practices have been introduced within the company for less than 1 year, between 1 and 2 years, between 3 and 5 years, between 6 and 10 years and 11 years or more. Table 4 shows their distribution for the sample. The intensity of implementation is measured by the mean of the percentage of workers participating in each work practice. The average percentage in problem-solving groups is 9.86 % (s.d. = 17.93), whereas that for work teams is 13.14 % (s.d. = 25.22).

INSERT TABLE 4

4.3. Estimation model

In order to test for the existence of direct and indirect effects, we have used path analysis. This facilitates the analysis of the sequential relationships studied making a clear distinction between direct and indirect effects. In all cases the coefficients were estimated using OLS regressions. The first model has communication improvement as dependent variable and ICT as independent variable. The second model explains operational performance and includes both communication improvement and ICT variables as dependent variables. The third model contains final performance as dependent variable and communication, operational performance and ICT variables as independent variables.

Several groups of models were estimated. Firstly, the models were estimated based on independent variables, such as the total number of ICT by number of years of use, the number of organizational innovations by number of years of use, ICT intensity and organizational innovation intensity.

Secondly, the models were estimated according to each group of ICT use (general use, communication and market-oriented ICT), to test whether their impact on the dependent variables was similar. However, the correlation among these variables led to collinearity problems when all were incorporated simultaneously into the models. For this reason, three different groups of models were estimated, including in each of them variables relating to each group of ICT.

As control variables, we have included in all the models number of workers (size) and type of industry. Type of industry has been captured through dummy variables for the following industries: food and beverage; metal; chemistry, plastics and non-metal and electric and electronic machinery. The omitted category is “Other industries”.

5. Results

5.1. Effect of ICT on performance: General Findings

Table 5 shows the effect of the number of ICTs implemented, their intensity and years of use on communication improvement and operational and final performance measures. The organizational innovation effect on ICT impact is also examined. The estimated linear regression models are statistically significant at the 1% level. Likewise, given the R-squared values, the regressions explain a high percentage of the variability in the dependent variables.

The number of ICTs has a significant impact on communication improvement. This effect is also found in relation to ICT intensity (hypothesis 1a is supported) As expected, the results from the second model in this table also show that communication improvement leads to

better operational performance. It can also be observed that the coefficients for ICT variables decrease substantially when compared to the first model. In fact, just one of ICT variables and the ICT intensity variable remain statistically significant once we control for communication improvement (hypotheses 1b, 2 and 2a are supported).

The third model reveals that communication improvement and operational performance are associated with better final performance. The size of the coefficients confirms that the positive effect of communication on final performance takes place mainly through operational performance. The coefficients of all ICT variables lack statistical significance. Taken together, all these results demonstrate the importance of indirect effects to understand ICT impact on performance. ICT positive effects on final performance are mostly due to the positive impact on communication improvement and, to a lesser extent, to the positive direct effect on operational performance. Therefore, hypotheses 1c, 2 and 2b are supported.

INSERT TABLE 5

With respect to the complementary effect of organizational innovations on ICT impact on communication improvement, no statistically significant positive effect is registered at least after one year subsequent to their introduction. The largest coefficients are found for the number of organizational innovation practices adopted at least ten years ago. However, contrary to expectation, the intensity of organizational innovations appears to have a statistically significant slightly negative effect on ICT impact on external and internal communication. With respect to operational and final performance, estimations indicate that, once we control for communication improvement, the effects of organizational innovation are substantially diminished and, in the case of final performance, they even completely disappear. We should note that the direct effect of organizational innovation intensity on operational performance is positive. Hence, hypothesis 3 is supported.

With regard to the rest of hypotheses, findings show that there are both immediate and long-term effects for all of ICT on communication, as shown by the statistical significance of the positive coefficients of the number of ICT variables in model 1 of Table 5. Therefore, hypothesis 4 and 5 are confirmed. It can also be observed that their benefits are larger the longer the technologies have been in use. It means that long-term impact is greater than immediate effects (hypothesis 6 is supported). The same applies with regard to the direct effects on operational performance displayed in Table 5.

The results also point to a larger ICT impact on communication improvement in larger firms. This could be related to their greater needs of coordination, what could make ICT more useful to this kind of companies. Regarding industry, results suggest that ICT effects are quite similar across manufacturing sectors.

5.2. Effect of general ICT-use

Figure 1 shows the impact of General ICT - computers and the Internet - on the various dimensions of performance. All models are statistically significant at the 1% level. All of them explain a high degree of variability in the performance variables (see R-Squared).

INSERT FIGURE 1

ICT have a positive and immediate effect on communication improvement, as shown by the statistical significance of the coefficient of the variable capturing the number of general-use ICT adopted in the last year. Later, and after the first year of adoption, even stronger positive effects are registered. The longer general ICT has been in use, the greater its impact on external and internal communication. It is also worth mentioning the positive effects detected for general-use ICT intensity. Therefore, hypotheses 1a, 4, 5 and 6 for general-use ICT have been supported.

Most of these results remain the same when analyzing the effects on operational performance controlling for the impact on communication. The number of general-use ICT

used longer than three years is associated to greater impacts of ICT on operational performance. The same applies to the intensity of use of this type of ICT. However, in the case of final performance all these positive direct effects disappear once the effects on communication and operational performance are taken into account. These results suggest that hypotheses 2b and 2c are also accepted in the case of general ICT.

5.3. Effects of Communication Technologies

As Figure 2 shows, there are no immediate impacts of these technologies on communication improvement. Their impact does not emerge until at least one year since their implementation. From that moment on, email, intranet and extranet allow the firm to better manage communication within and outside the company. Results reveal that the greatest impact takes place between three and five years after ICT adoption. Therefore, hypothesis 6 is supported, whereas hypothesis 4 is rejected. Hypothesis 5 is also accepted, despite the strongest effects found in the medium-term.

In the second model none of the variables measuring the number of communication ICT adopted is statistically significant. Only the variable referred to their intensity of adoption shows a positive and significant coefficient. It involves that communication- ICT has no direct effect on operational performance but an indirect one through communication improvement.

Finally, the model including final performance as dependent variable presents negative and significant coefficients for variables capturing the number of communication ICT. It means that their direct effect on final performance is negative. Therefore, the computation of indirect effects is needed in order to test hypothesis 1c. For example, in the case of the number of communication ICT adopted longer than five years ago, this effects would be $0.296 \times 0.794 \times 0.802$, where 0.296 is the impact of the ICT variable on communication, 0.794 the impact of

communication on operational performance and 0.802 the impact of operational performance on final performance. As a consequence, this indirect effect amounts to 0.188, what is larger in absolute value than 0.055, the negative direct effect found in model 3. The same computation for the other two ICT variables leads also to the conclusion that positive indirect effects are larger than negative effects, so hypothesis 1c is accepted.

INSERT FIGURE 2

5.4. Effect of market-oriented ICT

Finally, when analyzing web pages and the effect of electronic commerce market ICT on firm performance (Figure 3), all the estimated models are found to be statistically significant at the 1% level. All account for a high proportion of the variability in the selected variables (see R-Squared).

Both technologies have a positive and statistically significant effect on communication improvement, a higher impact being detected when they had been adopted three or more years earlier. Therefore, for this type of technologies, both short and long-term effects are confirmed. ICT effects increase as technologies are implemented, from the first to the third year, with a slight decline after the fifth year. It means that hypotheses 1a, 4 and 5 are supported. Our results also support hypothesis 6, although it should be taken into account that impacts are similar for three and five years in use to for longer than five years.

INSERT FIGURE 3.

Contrary to expectation, ICT intensity (measured as the percentage of sales and purchases via the Internet) is not statistically significant for any of the performance variables. This result may be due to the fact that the degree of development of e-commerce for Spanish manufacturing firms, especially small companies, is still relatively limited (INE, 2007).

6. Discussion and Conclusions

This paper provides empirical evidence on the direct and indirect impact of ICT on different dimensions of performance in Spanish SMEs. These relationships are explored within the framework of the resource-based view using path analysis and taking into account time-lags of the effects, as well as different types of technologies. In addition, we have also studied whether complementarities between technological and organizational resources may affect the managers' perception of ICT impact on firm performance.

Our findings show that ICT has a significant impact on the improvement of external and internal communication. Nevertheless, ICT direct impact on operational and final performance is limited. Impact on these two performance dimensions is mainly indirect through communication improvement. These results highlight the importance of indirect effects to understand ICT payoffs. This result is valid for the three types of ICT studied.

As expected, ICT impacts on perceived performance correlate positively with the experience of the company in using different types of technologies. We have also found that managers' perceptions of ICT impact are related to the adoption of new work practices. As for ICT, performance also depends positively on the time-period from when new work practices were first implemented. At least one year of previous adoption is needed for ICT impact on communication improvement to be noticed.

Our results highlight the relevance of using perceptual measures in the research on ICT payoff. Although this type of variables may present disadvantages over objective measures, it may provide new insights to better identify the processes through which ICT impacts on firm performance. For example, as shown in the paper, the relevance of improvements in external and internal communication to explain ICT effects on firm performance can only be empirically identified using perceptual measures. Our research confirms previous findings in

the literature with regard ICT value for firms. The finding of a positive link between ICT and firm performance is especially important, given the large share of SMEs in the economic activity of most countries. Therefore, ICT adoption in SMEs should be encouraged in order to improve their competitive position.

Our findings also suggest that competitive advantage can be the result of the adequate combination of different types of information technologies and work practices. To take full benefits of ICT investment, firms should make efforts to adopt organizational practices aimed at increasing teamwork and worker participation in decision-making. Complementarities found between both types of innovations suggest that managers should not consider ICT adoption isolatedly, but along with additional changes in job design.

Positive ICT impacts have been found both in the short and long-term. Nonetheless, these beneficial effects appear to be larger the longer these technologies have been in use. This result suggests ICT adoption is a complex process requiring continuous attention and surveillance from managers. To reap potential full benefits, a long-term approach should guide firms. Therefore, short-term pressures are not the best scenario for ICT investment.

One of the most robust findings lies on the positive impact of ICT on communication and the minor direct effect on operational and overall performance. As a consequence, it might be inferred that firms with larger coordination needs may benefit more from ICT adoption. This would be the case of firms dealing with more frequent and complex information flows usually associated with a large number and variety of agents involved.

Finally, this paper provides empirical evidence for a country in which the level of ICT adoption is below the European average and where ICT payoff for SMEs has been hardly analyzed (Sánchez, *et al.*, 2006). Within this context, and given that the literature has generally addressed large firms in countries with higher ICT penetration, our findings may be of interest to other researchers to identify how managers in SMEs perceive the benefits

derived from their ICT investment. Our results point to the significance of enhancing ICT adoption among SMEs and to the need for specific policies to overcome their lag, as compared with large firms.

Some limitations on this research should also be mentioned. The selected geographical area where the survey was conducted may be considered too limited. Further research should consider extending the geographical scope of the sample, including other regions and countries. It is also noteworthy that, as we used cross-sectional data, it has not been possible to study lagged effects for the intensity of the implementation of ICT resources and new work practices. Although interesting results have been obtained from our time analysis, it would be interesting to test whether the effects detected are also registered for the intensity of both ICT and organizational innovations by using panel data. Another potential limitation is related to the use of perceptual measures provided by the person who has made the decision about ICT adoption, what could give rise to a halo effect.

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Table 1.

Managers' perceptions of ICT payoff. Mean and standard deviation

Impact on business processes and overall firm performance	Mean	Std. dev.
Increase in productivity	4.84	2.67
Reduction in costs	4.71	2.43
Increase in market share	4.01	2.47
Increase in margin and profits	4.41	2.51
Development of new products, services and processes	4.46	2.57
Improvement of product and service quality	4.63	2.56
Improvement of speed of product delivery	4.24	2.66
Improvement of external communication	6.93	2.62
Improvement of coordination and internal communication	5.41	2.95

Note: The effects are assessed on a 0 (no effect) to 10 (very significant) scale.

Table 2.*Adoption of ICT within the SMEs: Length of implementation*

General-use ICT	No	< 1 year	1-2 years	3-5 years	>5 years
<i>Computers</i>	0.4 %	0.4 %	2.7 %	6.8 %	89.8 %
<i>Internet</i>	1.9 %	1.1 %	10.9 %	51.1 %	35 %
Communication-integrating ICT	No	< 1 year	1-2 years	3-5 years	>5 years
<i>Intranet</i>	31.3 %	2.8 %	10.3 %	35.3 %	20.2 %
<i>Extranet</i>	71.6 %	0.4 %	5.2 %	14 %	8.7 %
<i>Email</i>	2.6 %	0.8 %	10.2 %	50 %	36.5 %
Market-oriented ICT	No	< 1 year	1-2 years	3-5 years	>5 years
<i>Web</i>	37.2 %	4.7 %	15.5 %	23.3 %	19.4 %
<i>E-commerce</i>	76.8 %	1.6 %	7.1 %	9.4 %	5.1 %

Table 3.*Usage and infrastructure intensity of ICT. Mean and standard deviation*

General-use ICT	Mean	Std. dev.
<i>Computers per worker</i>	0.288	0.251
<i>Percentage of workers using computers</i>	28.60	22.69
<i>Percentage of workers using the Internet</i>	24.04	21.30
<i>Percentage of ICT expenses on total expenses</i>	3.45	3.03
Communication-integrating ICT	Mean	Std. dev.
<i>Percentage of workers using email</i>	25.18	21.43
<i>Percentage of workers using intranet/extranet</i>	22.05	22.84
Market-oriented ICT	Mean	Std. dev.
<i>Percentage of sales via the Internet</i>	1.76	6.64
<i>Percentage of purchases via the Internet</i>	1.23	3.22

Table 4.*Implementation of organizational innovation within SMEs: Incidence and length*

	No	< 1 year	1-2 years	3-5 years	6-10 years	> 10 years
Problem-solving groups	36.2 %	2 %	12.6 %	18.3 %	15.8 %	15.1 %
Work teams	49.4 %	2.4 %	9.8 %	12.2 %	12.2 %	14 %

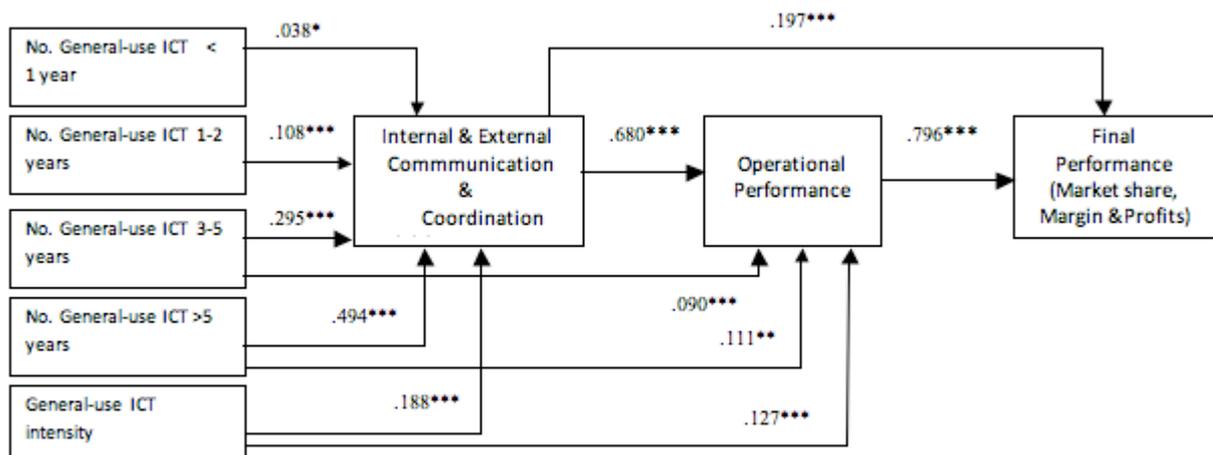
Table 5. *Joint impact of number and intensity of ICT and organizational innovation on managers' perceptions of ICT payoff in SMEs*

	Communication	Operational performance	Final performance
No. ICT < 1 year	.064*** (3.001)	-.001 (-.031)	-.025 (-1.338)
No. ICT 1-2 years	.150*** (6.100)	.000 (-.011)	-.029 (-1.275)
No. ICT 3-5 years	.309*** (9.354)	.063 (1.633)	-.048 (-1.445)
No. ICT >5 years	.360*** (9.572)	.091** (2.049)	-.059 (-1.543)
ICT intensity	.166*** (4.040)	.106** (2.515)	-.025 (-.665)
No. OI < 1 year	-.024 (-1.104)	.036* (1.668)	.023 (1.221)
No. OI 1-2 years	.097*** (3.924)	.039 (1.567)	.027 (-1.251)
No. OI 3-5 years	.084*** (3.066)	-.001 (-.032)	.018 (.738)
No. OI 6-10 years	.073** (2.534)	.037 (1.269)	.021 (.827)
No. OI > 10 years	.129*** (4.566)	.051* (1.742)	-.024 (-.925)
OI intensity	-.075** (-2.494)	.059* (1.943)	-.003 (-.115)
Size	.066* (1.952)	.021 (0.626)	.019 (.649)
Food and beverage	.043 (1.558)	-.009 (-.325)	.034 (1.426)
Metal	.014 (.479)	-.021 (-.711)	.011 (.444)
Chemistry, plastics and non-metal	-.011 (-.443)	-.023 (-.912)	.045** (2.042)
Electric and electronic machinery	-.020 (-.856)	.004 (.180)	.005 (.261)
Communication		.659*** (10.094)	0.233*** (3.457)
Operational performance			0.808*** (14.237)
F	134.467***	128.442***	166.942***
R2	.903	.905	.930

Standardized coefficients, t-statistics in brackets

OI: organizational innovation. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

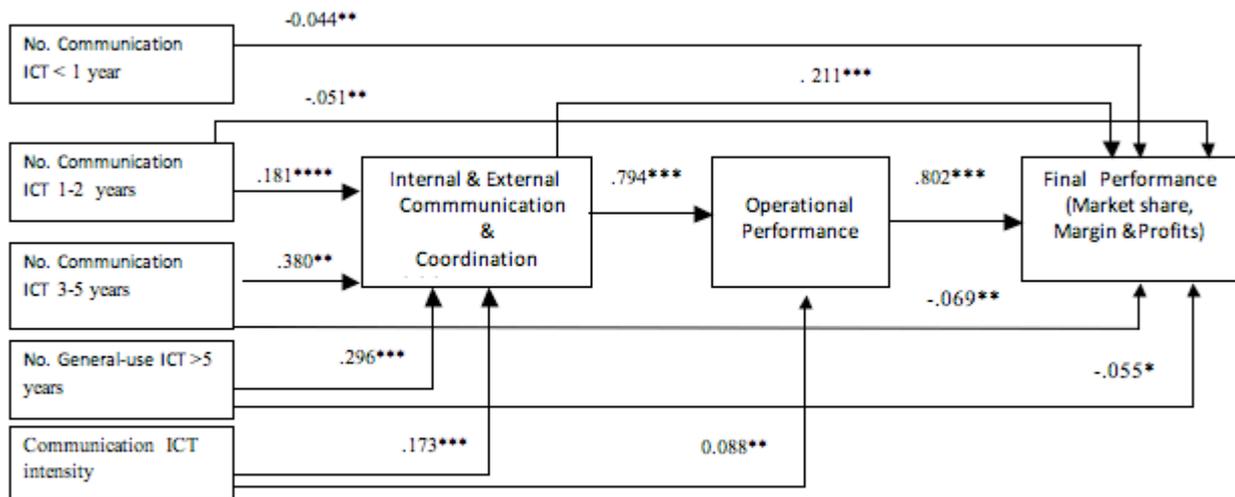
Figure 1. *Impact of number and intensity of General-use ICT on managers' perceptions of ICT payoff in SMEs*



Standardized coefficients, size and industry controlled for

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

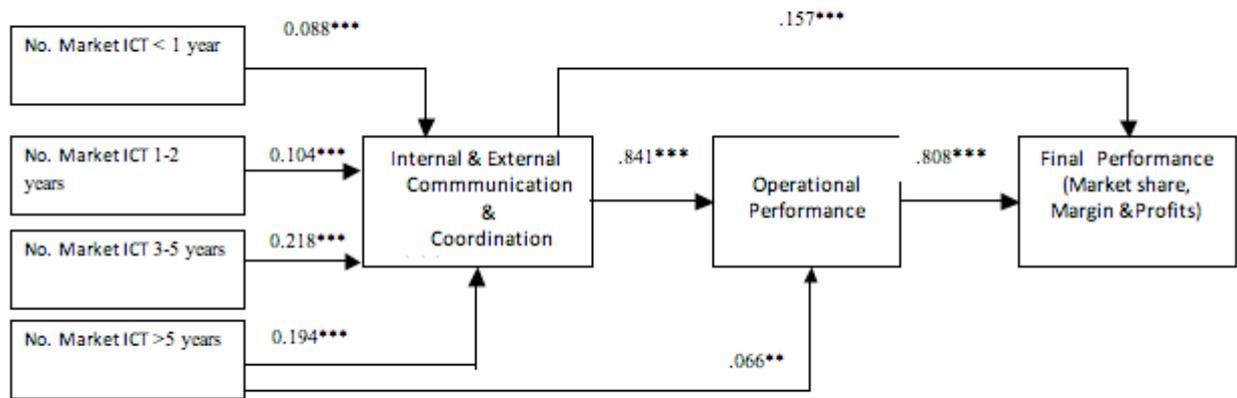
Figure 2. *Impact of number and intensity of Communication-integrating ICT on managers' perceptions of ICT payoff in SMEs*



Standardized coefficients, size and industry controlled for

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Figure 3. *Impact of number and intensity of Market-oriented ICT on managers' perceptions of ICT payoff in SMEs*



Standardized coefficients, size and industry controlled for

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.