

## Information Technology, Complementarities and Three Measures of Organizational Performance: Empirical Evidence from Spain

Ana Gargallo-Castel<sup>1</sup> Carmen Galve-Górriz<sup>2</sup>  
University of Zaragoza  
Spain

### Abstract

*The organizational impact of Information and Communication Technology (ICT) has generated considerable interest among academics in recent years. Nevertheless, though literature on this subject has grown substantially, research on Spanish firms has been scarcer. Therefore, it is necessary to examine the question in more detail. In this paper, survey data from 1225 Spanish firms has been used to analyze the impact of ICT and diverse complementary elements on three productivity measures. The results show the importance of organizational human capital in order to increase the benefits of ICT.*

**Keywords:** Productivity, gains, organizational performance, labor.

### Introduction

During recent years, information technology has received a great deal of attention, not only from the academic field, but also from the business world, because of its implementation in an increasing number of companies. Nevertheless, the results found in the literature are contradictory.

There is some degree of theoretical consensus about the existence of a positive relationship between ICT and performance. In particular, some authors argue that the implementation of ICT provides higher productivity, more satisfaction for the customer, more value creation, etc. However, other authors have found null or negative ICT effects on benefits, yield and share value. These studies support the productivity paradox, which is still under debate and which we will try to explain in this paper.

Moreover, in contrast to the extent of interest in these issues in other countries, mainly US, the organizational changes and labor productivity impacts of ICT have received little research attention in Spain. Because of it, the main objective of this study is to offer empirical evidence about the impact of ICT on the performance of Spanish firms, measured according to several productivity measures and taking into account the importance of complementary elements.

Although there are different explanations for the absence of a relationship between ICT and performance (such as, the difficulty of measuring costs and benefits), we propose that, unless

firms have complementary resources, they will be unable to make the most of ICT. This hypothesis allows us to offer an explanation of the Productivity Paradox.

According to the theory of complementarities, we consider that the benefits will be greater if ICT is used together with the adequate organizational resources and capabilities, specifically workers' qualifications, proactive direction and innovative culture, taking advantage of complementarities. Results suggest that firms' productivity improvements, as a result of the utilization of ICT, are directly related to the complementary resources of the firm. In particular, we offer evidence of the importance of workers' qualifications and proactive direction. These elements allow us to explain differences in productivity among firms with similar levels of ICT capital. Therefore, firms should keep in mind these complementary elements if they want to obtain improvements in productivity and make the most of ICT. From the perspective of complementarities, part of the benefit of information technology can be explained by its use with other complementary resources.

The paper is structured as follows: First, a short literature review is provided. In the next section, hypotheses to test, according to previous literature review are proposed. Subsequently, the sample is presented, and the variables object of study, are introduced. In the fifth section the empirical study is carried out and the results are discussed. The last section highlights the most important conclusions, and proposes future research according to current limitations.

### **Review of the Literature**

The importance of ICT in today's organizations, in qualitative terms as well as with regard to investment, has led to a wide range of studies of the issue. Much of this research looks briefly at the early literature on ICT (Brynjolfsson and Yang, 1996). Many studies present contradictory evidence, obtaining weak or even no link between ICT and performance (Banker and Kauffman, 1988; Brynjolfsson, 1993; Davenport, 1996; Kettinger et al., 1994; Loveman, 1994; Roach, 1987; Strassmann, 1985, 1990; Weill, 1992; Wilson, 1993,1995), the so-called Paradox. As Solow (1987) explained, "you can see the computer age everywhere but in the productivity statistics."

Brynjolfsson and Yang (1996), among other authors, suggest several explanations for this apparent lack of relationship: problems measuring productivity or investment, delayed results, over-investment relating to agency costs, or a zero-sum game. (Although there is a positive effect for some firms, for others it is negative and at the industry level there is no change).

From the Resource-Based View (Rumelt, 1983; Wernerfelt, 1984; Peteraf, 1993; Barney, 1991) it is argued that a resource is strategic when it is scarce. Information and communication technologies are accessible to all firms, but the assets and capabilities required to bring about changes, in both organizational design and in other elements, are not. Herein lies the source of the differences in firms' success or failure when they introduce new technologies. In this respect, Powell and Dent-Micallef (1997) maintain that ICT alone does not provide sustainable competitive advantages: its use along with complementary human and organizational resources such as a flexible culture, the integration of ICT and the firm's strategy, is what allows firms to obtain competitive advantages.

Table 1. Principal explanations for the Productivity Paradox

Explanations	Authors
Measurement of outputs and inputs: Problems measuring information technology investment, problems measuring productivity, problems measuring information technology output IT.	Brynjolfsson, 1993; Brynjolfsson and Yang, 1996; Schreyer, 2001; Griliches, 1992, 1994, 1995; Oliner and Sichel, 1994
Lags due to learning and adjustment, delayed results.	Schreyer, 2000; Cornella, 1994; National Science Foundation and National Science Board, 2000
Problems of over-investment relating to agency costs that motivate managers to invest for their own interest.	Brynjolfsson and Yang, 1996
Redistribution and dissipation of profits: Although there is a positive effect for some firms, for others it is negative and at the industry level there is no change (Zero-sum game).	Brynjolfsson and Yang, 1996
Lack of appropriate control factors and problems related to sample bias.	Dos Santos et al., 1993; Hitt and Brynjolfsson, 1996; Lucas, 1993

*Source:* Own elaboration

Other authors speak of the need to find a close fit between the management of ICT and complementary resources such as strategy, the organizational structure, human resources, and organizational resources, (Walton, 1989; Bélanger, 1998; Powell and Dent-Micallef, 1997; Bresnahan *et al.*, 2002; Ramírez, 2001).

Bresnahan *et al.* (2002) empirically analyze how combining ICT and organizational design positively affects firm productivity. Lichtenberg (1995) and Brynjolfsson and Hitt (1996; 2003) find that the gross marginal profit associated with ICT investment outweighs its marginal cost. Other studies obtain similar results for the distribution (Reardon *et al.*, 1996; Broersma *et al.*, 2003) or banking sectors (Prasad and Harker, 1997).

For the Spanish case, DMR Consulting-Aetic (2005) have found a positive relationship between information and communication technologies and productivity in various sectors, along with declining marginal returns, indicating that improvements in productivity are losing force over time.

After reviewing the research where inconclusive results have been obtained, in this current paper we argue that simply investing in ICT does not generate improvements in performance. Rather, it is the simultaneous presence of complementary resources - and the use of these in close alignment with these technologies - that can explain the differences.

Powell and Dent-Micallef (1997) find that the coefficients associated with ICT present a negative value in performance, while these coefficients become positive for the firm's pre-existing complementary resources, such as human and business resources. Loveman (1994), in early research on manufacturing firms, finds evidence of net marginal profits for other capital but not for IT. This is due to the lack of complementary changes.

### Proposal of the Hypotheses

According to previous literature, the need for capabilities and assets complementary to ICT, allows us to propose the first hypothesis. We suggest that ICT alone will be a poor predictor of productivity at firm level, since it does not generate improved results in and of itself.

***Hypothesis 1: “Information and communication technologies will be a poor predictor of productivity, not generating significantly improved results in and of itself”***

On the contrary, complementary resources and capabilities will be needed in order to implement effectively and to reap benefits from ICT investments. How these technologies are combined within a firm will determine the level of efficiencies achieved.

Among the factors analyzed, one of the most important is related with human resources – commonly studied as a determining factor of productivity, but not as a complementary element of ICT (OCDE, 2001a). Skilled employees allow firms to integrate ICT more effectively in the planning process of the business, to conceive and develop applications that cut costs or improve the product faster than the competition (Bharadwaj, 2000). Various studies have found that ICT investment has more effect on output when it is complemented by a high level of skill among the workers, and that the effect of ICT is greater when it is combined with an increase in the number of better-qualified workers and a reduction in the number of less-qualified ones (Powell and Dent-Micallef, 1997; Pinsonneault and Kraemer, 1997; Francalanci and Galal, 1998 and Bresnahan *et al.*, 2002). Therefore, the next hypothesis is defined as follows:

***Hypothesis 2: “The impact of ICT on results will be greater for organisations that combine ICT with a high level of workers’ qualification”***

As Orlikowski and Iacono (2000) highlight, however interesting the technology is, it will not be effective unless the organizational conditions facilitate its use. In order to make the most of information technology, it needs to be part of a strategic business decision, not merely a technological one (Goldberg and Sifonis, 1998).

An element that must be closely aligned is the attitude of managers toward the technologies. Innovation studies confirm that senior management support is related positively to the successful adoption (Meyer and Goes, 1988) and implementation of information systems (Premkumar and King, 1992; Grover, 1993). Senior management support will allow ICT to be reflected in the strategy and will ensure the necessary funding is provided to implement and integrate ICT, as well as to guarantee the required future financing (Kettinger *et al.*, 1994). Tallon *et al.* (2000) stress the importance of the characteristics of the CEO, and Brynjolfsson and Hitt (1997) find that “ICT-extrovert” firms enjoy slightly higher productivity than the rest. A firm with a proactive attitude within senior management is more likely to have a specialized group of people to work with new needs and innovations, which may lead to a major performance of the information and communication technologies adopted.

In conclusion, if there is commitment on the part of management, ICT can achieve its maximum efficiency. Specifically, the next hypothesis is hereby defined as follows:

***Hypothesis 3: “The impact of ICT on results will be greater for organisations that combine ICT with a proactive attitude of management toward the new technologies”***

Many authors have considered the importance of carrying out organizational changes in the firm so as to make an appropriate fit between the organizational and technological elements.

Technology strategy refers to the degree to which a firm progressively pursues technological change in terms of process innovation (i.e. up-to-date production technologies and equipment), product innovation or technological forecasting activities (Teo and Pian, 2003).

New processes and practices such as job re-design (Verdin, 1988) may then be more beneficial. In this line, Ramírez (2001) finds that the adoption of workers’ involvement models, TQM and re-engineering, positively influence the impact of ICT on results. Specifically, according to a Price-Waterhouse study (Price Waterhouse, 1995), most executives feel that the restructuring of processes is essential for ICT to be adequately used. Firms that are able to carry out such changes will achieve better results from their ICT. Therefore, the following hypothesis is defined as follows:

***Hypothesis 4: “The impact of ICT on results will be greater for organizations that combine ICT with process innovations”***

### **Sample and Definition of the Variables**

In order to verify the proposed hypotheses, we use the information originating from the Survey on Business Strategies (SBS). This survey is carried out yearly by the Spanish Ministry of Science and Technology. We selected this source since it includes a statistically representative sample of the Spanish population of manufacturing firms (Fariñas and Jaumandreu, 1999).

The total number of manufacturing firms in the SBS for 1998 was 3072. After selecting all firms for which the database provided the necessary information, a final sample of 1225 firms was obtained. Based on the collected information, we have defined several measures of firm performance and those variables that, in accordance with the specialized literature, could have an impact on them. Specifically, the following variables have been defined to carry out the empirical analysis:

**a) Dependent Variables:** Among the performance measures, one of the most used in the literature is productivity and marginal product (Brynjolfsson and Hitt, 2003), using different samples, sectors and methodologies (Barua *et al.*, 1995; Krueger, 1993; Mahmood and Mann, 2000). Following previous research, in this study we use three different measures of labor productivity:

- **Productivity 1 (PDT\_1):** First performance variable has been measured by using value added per employee of the firm.
- **Productivity 2 (PDT\_2):** Next performance variable has been measured by goods and services produced per employee of the firm.
- **Productivity 3 (PDT\_3):** Last dependent variable has been measured by how much value added a worker produces per hour worked.

**b) Independent Variables:** According to previous research, independent variables at firm level have been defined as follows:

- **ICT capital intensity** ( $K_{ICT}/L$ ): This variable has been defined as the amount of ICT capital per unit of labor input. It has been measured by ICT stock divided by number of employees for the entire firm. ICT stock is estimated using the perpetual inventory method that cumulates investments carried out over time in computer equipment and data processing equipment by the firm, assuming a depreciation rate of 0.20\*.

- **Intensity of rest of capital** ( $K_{NICT}/L$ ): This variable includes non-ICT capital intensity. It is measured by conventional capital, calculated as the difference between the total net fixed assets (obtained from the balance sheets) minus the part of net fixed assets corresponding to ICT, divided by the total number of employees of the firm. Although Lichtenberg (1995) argues that this is an imperfect measure of capital, due to the use of accounting depreciation rather than economic depreciation, and historic values rather than replacement values, this is not problematic because the ratios “historic value/real value” and “accounting depreciation/economic depreciation” remain constant for all the firms in a sector, and including a sectorial dummy variable, as we do, removes any bias.

**c) Multiplicative dummy variables:** We have added three multiplicative dummy variables that reflect the interaction of ICT and each complementary element: workers’ qualification, proactive direction and innovation of process:

- **ICT and workers’ qualifications (ICTQUAL):** From this classification we build a variable capturing the interaction between the presence of ICT in the firm and qualified staff, measured as the existence of a higher than sector-average number of qualified workers in the firm. The multiplicative variable takes a value of 1 when the firm has more qualified workers than the sector average, along with positive ICT stock, and 0 otherwise. We approximate the workers’ qualifications variable by the educational level completed by the workers (OCDE, 2001b), distinguishing two types: *qualified workers*, which includes workers with university qualifications, trained technicians, experts and assistants; and *unqualified workers*, which includes all workers who lack any prior academic training.

- **ICT and Management attitude (ICTMAN):** The management attitude variable reflects the involvement of senior management in the implementation of the new technology measures, whether “there exists a committee for technology and R&D in the firm”, or “a plan for innovation activities”, or if “the firm uses some indicator to measure the results of innovation”. The multiplicative variable takes a value of 1 when the firm practices one or more of these activities and it has ICT capital, and 0 otherwise.

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\* Depreciation rates close to 20% have been recently used, for example by Kafouros (2006), who assumes a depreciation rate for intangible technological resources of 20% or Shin (2000, 2006) who uses a depreciation rate of 22.4 % for ICT investments. In any case, though rates used in previous studies vary widely, Bloom et al. (2005) show that the significance and the magnitude of the coefficient obtained for ICT is not affected by the exact choice of the alternative depreciation rate.

- **ICT and Innovation of process (ICTPROC):** The innovation of process measures whether the firm has carried out innovations of process in the period of study. The multiplicative variable takes a value of 1 when the firm carries out innovations of process and it has ICT capital, and 0 otherwise.

**d) Control Variables:** Based on previous studies, the following variables have been included as independent control variables to proxy for industry characteristics, legal structure of the firm and organizational size:

- **Sector of activity ( $D_s$ ):** This variable is defined by first two digits according to the Spanish National Classification of Economic Activities (CNAE) Code.
- **Legal structure of the firm ( $D_{LS}$ ):** This variable allows us to control the effect of the diversity of corporate structure that appears in the sample (limited liability company, public limited liability company, cooperative, Employee-owned Limited Liability Company).
- **Size (Size):** Firm size variable is measured through the total number of employees of the firm.

Table 2 presents the main statistics of the variables for the total sample.

Table 2. Main statistics of the sample

	Mean	Standard Deviation
ICT intensity	107.57	227.21
Rest of capital intensity	7495.05	13226.88
Size	261.03	660.91
Productivity 1 (VA / N° workers)	6.73	4.65
Productivity 2 (Goods and services/ N° workers)	23.54	23.28
Productivity 3 (VA / worker-hour)	3.78	2.65
Total number of firms	1225	

Source: Own elaboration

### Methodology and Empirical Analysis

To test the hypotheses we use a methodology that allows us to include the effects of ICT, together with adequate organizational and human resources. Following previous studies, we use a standard production function to model the production process, considering ICT as a factor of production (Hitt and Brynjolfsson, 1996; Lichtenberg, 1995; Brynjolfsson and Hitt, 1996; Gurbaxani *et al.*, 1998; Ramírez, 2001).

We consider a Cobb-Douglas production function. The formulation of this function has been shown to be consistent in this context (Loveman, 1994; Dewan and Min, 1997). Various dummies are included to represent the interaction of ICT with various complementary resources. We include these variables since, from a statistical perspective the models in which the interrelations are significant offer more accurate estimates than those that assume an absence of interrelations between explanatory variables.

The coefficient of these multiplicative dummies will indicate the direction of the joint effect of their components (a negative/positive sign indicates that both variables combined will negatively/positively affect productivity).

In order to gather more evidence about whether the hypotheses that we have advanced should be accepted or rejected, we specify three models.

$$\textbf{Model 1: } \text{LnPDT}_{-1i} = \alpha + \beta_1 \text{Ln} (K_{\text{ICT}}/L) + \beta_2 \text{Ln} (K_{\text{NICT}}/L) + \beta_3 \text{Ln} \text{SIZE} + \gamma_1 \text{ICTQUAL} + \gamma_2 \text{ICTMAN} + \gamma_3 \text{ICTPROC} + \Sigma \zeta_{LS} D_{LS} + \Sigma \zeta_S D_S + \varepsilon$$

$$\textbf{Model 2: } \text{LnPDT}_{-2i} = \alpha + \beta_1 \text{Ln} (K_{\text{ICT}}/L) + \beta_2 \text{Ln} (K_{\text{NICT}}/L) + \beta_3 \text{Ln} \text{SIZE} + \gamma_1 \text{ICTQUAL} + \gamma_2 \text{ICTMAN} + \gamma_3 \text{ICTPROC} + \Sigma \zeta_{LS} D_{LS} + \Sigma \zeta_S D_S + \varepsilon$$

$$\textbf{Model 3: } \text{LnPDT}_{-3i} = \alpha + \beta_1 \text{Ln} (K_{\text{ICT}}/L) + \beta_2 \text{Ln} (K_{\text{NICT}}/L) + \beta_3 \text{Ln} \text{SIZE} + \gamma_1 \text{ICTQUAL} + \gamma_2 \text{ICTMAN} + \gamma_3 \text{ICTPROC} + \Sigma \zeta_{LS} D_{LS} + \Sigma \zeta_S D_S + \varepsilon$$

Where  $\beta_i$  represent the output elasticities of ICT capital, non-ICT capital and labor, respectively, different for each of the three models. Pairwise correlation analysis between variables employed in this study is shown in Table 3, where we found that there were no problems of correlation between any of the independent variables. It suggests no multicollinearity problems in the estimation model.

Table 3. Correlation Matrix

		Ln ( $K_{\text{ICT}}/L$ )	Ln ( $K_{\text{NICT}}/L$ )	Ln SIZE	LnPDT_1	LnPDT_2	LnPDT_3
Ln ( $K_{\text{ICT}}/L$ )	Correlation Coefficient	1.000	0.303 <sup>+</sup>	0.318 <sup>+</sup>	0.384 <sup>+</sup>	0.341 <sup>+</sup>	0.383 <sup>+</sup>
	Sig. level	.	0.000	0.000	0.000	0.000	0.000
Ln ( $K_{\text{NICT}}/L$ )	Correlation Coefficient	0.303 <sup>+</sup>	1.000	0.357 <sup>+</sup>	0.459 <sup>+</sup>	0.468 <sup>+</sup>	0.459 <sup>+</sup>
	Sig. level	0.000	.	0.000	0.000	0.000	0.000
Ln SIZE	Correlation Coefficient	0.318 <sup>+</sup>	0.357 <sup>+</sup>	1.000	0.377 <sup>+</sup>	0.343 <sup>+</sup>	0.383 <sup>+</sup>
	Sig. level	0.000	0.000	.	0.000	0.000	0.000
LnPDT_1	Correlation Coefficient	0.384 <sup>+</sup>	0.459 <sup>+</sup>	.377 <sup>+</sup>	1.000	0.583 <sup>+</sup>	0.977 <sup>+</sup>
	Sig. level	0.000	0.000	0.000	.	0.000	0.000
LnPDT_2	Correlation Coefficient	0.341 <sup>+</sup>	0.468 <sup>+</sup>	0.343 <sup>+</sup>	0.583 <sup>+</sup>	1.000	0.583 <sup>+</sup>
	Sig. level	0.000	0.000	0.000	0.000	.	0.000
LnPDT_3	Correlation Coefficient	0.383 <sup>+</sup>	0.459 <sup>+</sup>	0.383 <sup>+</sup>	0.977 <sup>+</sup>	0.583 <sup>+</sup>	1.000
	Sig. level	0.000	0.000	0.000	0.000	0.000	.

<sup>+</sup>Correlation is significant at the 0.001 level (2-tailed).

We obtained positive coefficients for the variable ICT intensity in the three models. However, if the coefficient of this variable is compared with that corresponding to conventional capital, its value is much lower, which indicates that its impact on each of the three measures is considerably weaker than that of the rest of the capital. This allows us to accept Hypothesis 1 postulating the weak effect of ICT on the results.

While ICT rarely has a direct impact, the multiplicative dummy representing ICT and qualifications takes on positive values, confirming the importance of qualifications. This allows corroboration of Hypothesis 2. These results are in accordance with the studies that found that the use of equipment for data processing is mainly in the hands of workers with medium and high skills (Borghans and Ter Weel, 2007; Borghans and Ter Weel, 2006; Bresnahan et al., 2002).

As for the variable measuring ICT and proactive management, positive coefficients are obtained in all three models, although with a lack of statistical significance in the case of productivity measured by value of goods and services per employee. Hence, we can conclude that Hypothesis 3 is accepted in two of the three models. Finally, the dummy capturing the relationship between ICT and innovation of process is not significant in any of the models, leading us to conclude that a redefinition of this variable would be advisable, since it is perhaps partly captured in the variable referring to the position of management. Thus, the results prevent us from accepting Hypothesis 4.

Table 4. Results of the productivity regression analysis

	Standard coefficients		
	Model 1	Model 2	Model 3
Ln (K <sub>ICT</sub> /L)	0.056**	0.075***	0.057**
Ln (K <sub>NICT</sub> /L)	0.362***	0.429***	0.355***
Ln SIZE	0.092***	0.020	0.101***
Personal Company	-0.017	-0.047**	-0.016
Limited Company	-0.102***	-0.141***	-0.098***
Labour Anonymous Company	-0.040*	-0.074***	-0.040*
Cooperatives of Associated Work	-0.034	-0.072***	-0.036*
Other legal structures	-0.008	-0.021	-0.009
ICTQUAL	0.124***	0.114***	0.126***
ICTMAN	0.060**	0.026	0.060**
ICTPROC	0.000	0.032	0.002
D <sub>s</sub>	Yes	Yes	Yes
R <sup>2</sup>	48.90%	49.38%	49.08%
Adjusted R <sup>2</sup>	48.00%	48.49%	48.18%
Total number of firms	1225	1225	1225

\*p<0,1; \*\*p<0,05; \*\*\*p<0,01

With regards to the legal structure of the firm, we can draw no conclusions, since the significance varies between the three models.

The three models achieve very similar levels of explanatory power – with a correlation coefficient of around 48% – and confirm the importance of ICT and its relationships to human resources (ICT and human resources management has positive and statistically significant coefficient in the three models).

## Conclusions

The results of the estimation allow us to conclude that, in order to increase the benefits of ICT, it is necessary to align various elements. Differences across countries may well be relevant in the determination of organizational ICT impact. The important issues such as government policies are clear. The need to increase and improve education and skills of workers to guarantee that firms can take full advantage of the ICT they have implemented is one of the questions that public authorities should take into account, given that policies play a key role in assuring that the potential gains in productivity defended by some authors materialize (OCDE, 2000).

In the current analysis, we show how the differences between Spanish firms in the effect of ICT on several measures of productivity can be explained by the use of these technologies with qualified workers, and a proactive attitude by managers.

Finally, this study is not exempt from limitations. The first limitation arises from the lack of cross-nation data sources. It prevents us from reaching conclusions about specific differences between countries. However, this study offers new empirical evidence and sheds some light on a topic where Spanish firms are under-represented by means of a methodology that allows us to include the effects of ICT use, together with adequate organizational and human resources. The second limitation arises from the lack of specification in the definition of ICT, which restricts our ability to distinguish among types of technologies. However, the Survey on Business Strategies database does not allow us to calculate separately the stock of different Information and Communication Technology. In addition, it is difficult to measure organizational characteristics, such as the presence of a culture open to innovation, or the skills of the employees, as well as to specify the levels of investment in Information and Communication Technology, since their introduction can refer to equipment of very diverse levels.

These limitations are related to research yet to be conducted and we would suggest, as possible lines of future research, a detailed analysis using new organizational and ICT measures, and a further study with cross-national data in order to extend the present study.

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<sup>1</sup> Ana Gargallo-Castel is assistant lecturer at the Department of Business Administration, University of Zaragoza (Spain). She can be reached at: Department of Business Administration. Fac. CC. SS. y Humanas. University of Zaragoza. Ciudad Escolar, S/N 44003-Teruel (Spain). E-mail: gargallo@unizar.es; Phone: +34 978- 61 81 00; Fax: +34 978-61 81 03.

<sup>2</sup> Carmen Galve-Górriz is associate professor at the Department of Business Administration, University of Zaragoza (Spain). She can be reached at: Department of Business Administration. Fac. CC. EE. y EE. University of Zaragoza. Gran Vía, 2 Zaragoza (Spain). E-mail: cgalve@unizar.es; Phone: +34 976- 76 27 14; Fax: +34 976-76 17 67.

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