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A Firm-level investigation of the complementarity between information and communication technologies and organizational resources

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Abstract

This article investigates the relationship among Information and Communication Technologies (ICT), complementary factors and productivity in a data set of 1269 Spanish firms. Using econometric modelling the analysis examines and measures the extent to which ICT and complementary human and strategic resources have contributed to firm productivity performance. The main findings from this paper suggest a complementary effect between ICT and those organizational factors. Thus the analysis demonstrates the importance of the strategic adjustment between technology and organizational factors, in particular, that ICT, human and quality investments may have wide-reaching consequences for the performance of the firm.

Keywords: Complementarities, Information and Communication Technologies, Quality strategy, Human resources, Firm performance

1. Introduction

Over the last decade, competition has intensified and companies have found the need to restructure and improve their business practices to find new and more efficient ways to obtain competitive advantage in order to survive. In this context, ICT offers benefits for a wide range of business processes and improves information and knowledge management within the firm, leading to better performance. According to OECD [1] in times of competition intensification and economical crisis there must be a focus on the contribution of ICT to innovation and growth. Recent years have witnessed a surge in interest in ICT impact. There has been considerable research about the impact of ICT on firm performance and

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importance of ICT as an essential enabler of business growth and economic development has been widely confirmed using both a growth accounting and at the firm level approach [2], [3]. Nevertheless, there has been little empirical evidence offering positive effects [4]. Moreover, recent research in this area has produced evidence of the importance of the combination of organizational change together with technological innovation. Technological innovation is not an isolated source of improvement, so, is required that firms accompany innovation with the development of complementary organizational practices [5].

Our objective in this paper is to analyze the impact of ICT on firm performance and whether innovation and organizational change are complementary. In order to reach this objective, we analyze the impact of technological innovation and diverse complementary elements on organizational productivity using a data set from more than a thousand Spanish firms. Our results contribute to the international body of research and offer a new conceptualization and empirical evidence of the technology innovation performance. We show the importance of organizational human capital in order to increase the benefits of the technological innovation.

We have structured the work into five parts, including this introduction. Section 2 summarizes the main findings in the literature. We offer a brief outline of the main studies investigating the extent of the relationship between ICT investments and firm performance including the effect of complementary factors. Section 3 outlines the methodology the data and variables used in the empirical analysis. Section 4 provides an estimate of the relative impact of ICT and complementary factors on firm productivity. Finally in section 5, we conclude with a summary of the results and their main implications.

2. Background literature and hypotheses

In the modern economy, challenges in the forces for globalization have increased the interest in the impact of information and communication technology on economic growth and on firm performance [6]. Although much of the early literature on ICT obtained contradictory empirical evidence, negative or irrelevant relationship between ICT and firm performance [7], [8], [9], [10], [11], [12], [13], [14], [15], [16] –offering support to the so-called Productivity Paradox-, more recent research in this area has produced evidence of the positive impact of ICT on a variety of measures of firm performance positive [17], [18], [19], [20]. It is argued that ICT reduces transaction and coordination costs, maximizing the value of the transactions [6]. It reduces the coordination costs of the firm because of lower procurement and inventory costs and closer coordination with suppliers [21], [22], [6]. Moreover, communication based on the Internet can also improve external communication, reducing the inefficiencies resulting from lack of co-ordination between firms, and increasing the speed and reliability of information processing and transfer.

Nevertheless, as ICT is widely available it can hardly generate sustainable competitive advantage [9], [23]. Conversely, critical value may reside in its use with complementary resources and capabilities of the firm [24], [25]. In this context, recent empirical literature has begun to re-assess the association between ICT and a wide variety of complementary factors [4], [26], [27], [28].

Following the literature reviewed, we are going to focus our attention on human capital and organizational practices. Regarding the importance of human capital, many authors have shown that benefits of using ICT are closely linked to the organisational design and skills of the organizational personnel who use them [29], [30], [31], [32], [23]. Skilled employees allow firms to integrate ICT more effectively [33], therefore ICT will have substantial impacts on firm performance when it is combined with a higher level of better-qualified personnel.

Along with human resources, reorganization and implementation of new practices have been widely highlighted as complementary resources [34]. Gretton et al. obtain empirical evidence of the positive

impact of complementarities between the use of ICT and human resources, innovative business practices, and intensity of organizational change on the productivity growth of Australian companies [35]. Crespi et al. examine the relationships between productivity growth, ICT investment and organisational change in UK firms, and their results support the idea that gains from IT need re-organisation [36]. Arvanitis and Loukis offer empirical evidence of the positive impact of ICT capital, human capital and new organizational practices on labour productivity in Greece and Switzerland [4]. Black and Lynch, who examine the impact of ICT, human resource practices, and firm reorganization on productivity [37]. Ramírez et al. highlight that positive influence of re-engineering and TQM on the impact of ICT on results [38]. Opportunities to decrease the costs of flows and information processing provided by ICT will offer new approaches to the implementation of quality assurance systems [39]. In conclusion, we can argue that in order to reap higher benefits from ICT investments, complementary organizational resources will be needed.

3. Methodology

In order to estimate the effects of ICT, we rely on an extended Cobb-Douglas production function, the most commonly used form for the production function, in which we include ICT capital as a factor of production to assess its contribution to productivity [40], [41], [42], [19], [43], [44]. Additionally, to test ICT effects in conjunction with appropriate organizational and human resources, we use a methodology that allows us to model the joint effects of ICT and organizational and human resources on performance. Various dummies variables that reflect the interaction of ICT with the complementary resources, are added. The production model to be estimated, including the effects of ICT and the importance of multiplicative variables, is defined according to the following equation (1):

$$Ln(Q/L) = \alpha + \beta_1 Ln(K_{ICT}/L) + \beta_2 Ln(K_{NICT}/L) + \beta_3 LnL + \alpha_1 ICT_{QUALIF} + \alpha_2 ICT_{QUALIT} + CV + \varepsilon \quad (1)$$

Where:
β_i represents the output elasticity of ICT capital, non-ICT capital and labour, respectively; A measure the total productivity factor and α_i refers to the multiplicative dummy variables.

Ln(Q/L) represents the labour productivity, measured using the value added by employee, in logs.

Ln(K_{ICT}/L) reflects the log of ***ICT capital intensity*** variable measured by ICT stock -computed using the perpetual inventory method and a depreciation rate of 20% [45]- divided by number of employees of the firm.

Ln(K_{NICT}/L) reflects the ***intensity of the rest of capital*** as the ratio between non-ICT capital and labour, in logs. Non-ICT capital is measured by conventional capital, calculated as the difference between the total net fixed assets minus that part of net fixed assets corresponding to ICT.

LnL represents the ***size*** of the firm measured as the total number of employees of the firm at the end of the year, in logs.

ICT_{QUALIF} captures the interaction between the availability of ICT capital in the firm and the intensity of qualified workers, measured as the existence of a higher than sector-average number of qualified employees in the firm. We classify as qualified those employees who have completed a university degree, or trained as technicians and experts. The multiplicative variable takes a value of 1 when the firm has more highly qualified workers than the sector average, along with positive ICT stock, and 0 otherwise.

ICT_{QUALIT} captures the interaction between the availability of ICT capital and activities related to quality carried out by managers in the firm. It takes a value of 1 if the firm has made efforts in standardization and quality control and, at the same time, it has ICT capital, and 0 otherwise.

CV includes sector of activity and legal structure of the firm as independent ***control variables***. Sector of activity dummy variables ($\boldsymbol{D_S}$) are defined by the first two digits according to the Spanish National Classification of Economic Activities (CNAE) Code; Legal structure of the firm ($\boldsymbol{D_{LS}}$) include a set of dummy variables in order to control for the effect of the diversity of corporate structure in our sample (limited liability company, public limited liability company, cooperative, Employee-owned).

The dataset used for the empirical analysis is drawn from the Survey on Business Strategies (SBS), an annual survey on a representative sample of Spanish manufacturing firms with 10 or more employees, compiled annually by the Spanish Ministry of Science and Technology. Firms participating in the survey were chosen according to a selective sampling scheme which offers a statistically representative sample of manufacturing firms in Spain [46], [47]. The total number of manufacturing firms in the SBS for the year 2002 was 1,724. Excluding those observations for which the database does not provide information for all necessary variables, we are left with a final sample of 1,269 firms. Table 1 presents the main statistics (mean and standard deviation) of the variables for the total sample:

Table 1. Descriptive statistics

	Mean	Standard Deviation
ICT intensity	2.0870	7.99527
Rest of capital intensity	10.0388	1.67310
Size	4.2065	1.45488
ICTQUALIF	0.3436	0,47509
ICTQUALIT	0.3034	0.45990
Productivity (VA / Nº workers)	0.0165	0.12762
Total number of firms	1,269	

4. Results and discussion

Table 2 presents parameters estimates for the model based on the extended Cobb-Douglas production function, according to the ordinary least squares method (OLS). The first issue to hightligh from Table 2 is that the model estimated presents a global fit that is satisfactory, as measured by the correlation coefficient. The model achieves an explanatory around 34% and confirms the importance of ICT and the interaction between those technologies and organizational complementary resources in improving firm performance. The coefficient of the ICT intensity variable takes positive values ($p<0,01$), postulating a positive effect of ICT on performance. Moreover, both the multiplicative variable representing ICT and qualifications interaction and the variable measuring ICT and quality strategy are positive and statistically significant ($p<0,10$ and $p<0,05$, respectively). These results are consistent with the studies that found that the use of equipment for data processing is mainly in the hands of workers with high skills [48], [49], [30] and those argue that ICT becomes really effective when it is handled proactively by management [50].

Table 2. Productivity estimates for ICT and complementary resources

	Standardized coefficients	Sign.
Ln (K_{ICT}/L)	0.068	0.008
Ln (K_{NICT}/L)	0.267	0.000
Ln L	0.126	0.000
ICT_{QUALIF}	0.073	0.025
ICT_{QUALIT}	0.052	0.062
D_{LS}	Yes	
D_S	Yes	
R^2	35.6%	
Adjusted R^2	34.2%	
Total number of firms	1,269	

*** p<0,01; ** p<0,05; * p<0,10

Our results reinforce those obtained by Aral et al., who concluded that one reason for the variations in the returns to ICT investments across firms may be differences in the adoption of complementary organizational practices [51].

5. Conclusion

This article provides new empirical evidence on the relationships among ICT and organizational factors and their impact on firm performance. Our main contribution lies in the possibility of offering evidence supporting the existence of a statistically significant relationship, not only between ICT and productivity, but also between the multiplicative variables that represent ICT and other complementary factors. Our results emphasize the importance of considering organizational aspects in order to raise all of the potential benefits of ICT. Those results are consistent with the complementary theory and the hypothesis of organizational complementarity between ICT and skills developed by Bresnahan [52] and Bresnahan et al. [30] and allow us to conclude that complementary investments in organization and human resources skills are crucial in achieving higher levels of performance.

To conclude, it seems appropriate to indicate that this study has some limitations that point the way to further investigation. In future research, it would be interesting to include the time dimension to assess the impact of ICT investment on performance after a time lag, and compare this with earlier results.

Since there are few studies investigating the impact of ICT on firm productivity in Spain, the present study attempts to fill this gap. We have analyzed the role of the alignment of different elements in increasing the ICT impact, in a sample of Spanish manufacturing firms.

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