VOL 5 / ISSUE 1 / APRIL 2010 / 11-24

The relationship between human resources and information and communication technologies: Spanish firm-level evidence

Carmen Galve-Górriz[1] and Ana Gargallo Castel[2]

University of Zaragoza, Department of Business Administration
[1] cgalve@unizar.es, [2] gargallo@unizar.es

Received 21 July 2009; received in revised form 27 November 2009; accepted 17 February 2010

Abstract

Increased attention to the economic impact of information and communication technologies (ICT) underscores the impact of ICT on the social side of the “digital divide.” ICT and individual and organizational changes are often closely related. This paper examines the main characteristics of the relationship between ICT and human resources in Spanish firms, in the context of a developed country with an incidence-rate of ICT slightly below the average of its area. The data on 1,269 Spanish manufacturing firms has been taken from the Survey of Business Strategies (SBS) of the Fundación Empresa Pública (Spanish Foundation) of Spain. Our results suggest that ICT are related to higher levels of qualification, higher levels of R&D workers, and higher levels of training per worker. Moreover, firms that invest in ICT offer higher levels of average wages. These results confirm the relationship between technological innovation, and organizational and human changes. Managers and public administrators should take into account such mutual interrelations in order to optimize their decisions concerning investment in human and technological resources.

Key words: Human Resources, Technology, Training, Education, Organizational Change

1 Introduction

The Previous studies in several disciplines – management studies, economics, sociology - have analyzed the relationship between technological innovation and human resources ([23], [27], [45], [73]). In general, the widespread use of ICT has been associated with numerous changes in internal business processes, such as organisational structure, job design, requisite employee skills, and so on, aimed at improving flexibility [5], [13], [15]. More specifically, various studies [7], [13], [49] make the link, theoretically and empirically, between the employment effect of firms' ICT investments and the impact of ICT diffusion on organizational aspects related to human resources. Berman et al. [17] observe an increase in required skills during the 1980s in the manufacturing sector, which is partly attributed to the introduction of ICT. Using the same decade as a basis, [27] record how the proportion of qualified workers increased, due to the use of computers in firms. Bresnahan et al. [24] argue that firms and workers need to adapt to the use of ICT, and offer empirical evidence, at the firm level, about the relationship between new organizational practices and labor force characteristics. They find that firms that adopt innovation related to ICT, reorganization of work, and development of new products or services, tend to use more qualified workers. Finally, Landry et al. [55] review the changing nature of work in the age of e-business, and highlight significant changes in the life of the organization, coupled with a pronounced movement towards a job market of flexible, fluid groups of highly-skilled, entrepreneurial employees.

It may be that advances in ICT usage are exacerbating the difference in employability between the technology-savvy "haves" and "have nots," also known as the "digital divide". Recent studies point up the connections between ICT and social inequalities, their impact on wages, employment structure, professional skills, vocational training, etc. (e.g. [19]-[21], [47], [55]).

The aim of this paper is to analyse the presence of different standards between those firms adopting ICT, and those not doing so, especially in those aspects related to human resources. This analysis focuses on the case of Spain, where – as indicated by [42] – the examination of the impact and strategic analysis of ICT is still in its early stages. Furthermore, despite being regarded as a developed country, Spain is slightly below the European average, but is slowly making progress towards an information society, according to data from the Commission of the European Communities [30]. Spain is ranked 31st globally, below Czech Republic, Cyprus and Slovenia, according to "The Global Technology Report, 2008-2009" published by the World Economic Forum [74]. All of this makes it interesting to examine in depth the relationships between ICT and human resources among a group of firms in Spain. To examine these effects on Spanish firms, we first offer a literature review, selecting studies on the impact of ICT on inequality, followed by studies on the incidence of this impact on the growth and performance of organizations. Using firm-level data, we then examine the impact of ICT on the introduction of new work practices, as well as on the evolution of wage inequality. The results allow us to identify different groups of firms characterized by different strategic behaviors. Finally, the main conclusions of the article are presented.

2 Theoretical framework

As Milgrom and Roberts [58] indicate, a business firm can be regarded as a structure based on contracts between each of its agents, including its employees. The relationships and interdependencies that emerge among those agents require timely information in order to maintain coordination. Moreover, in high-pressure, competitive environments, there is an evident need to effect changes in the organization toward more flexible structures, where specialisation and continuous job-training are key [66]. In this context, ICT eases the coordination and flow of information, providing a necessary support for the firm [68]. The modification of the firm's organizational framework is thus made possible, giving way to complex organizations in the shape of a network, as opposed to the previous hierarchies based on centralization, and transferring a fundamental role to its employees through decentralization of decision-making [40], [50], [71].

The introduction of new technologies, and its connection with workforce changes, has been widely reviewed in the academic literature at the firm level [20], resulting in several analyses of the concept known as "skill-biased technical change" (SBTC). More specifically, SBTC analyses how the introduction of new technologies generates a bias towards more skilled workers, and causes a relative increase in the demand for skilled workers, since these skilled workers are needed in order to use the new technologies correctly [7], [16], [26], [34], [43]. A revolution will be slanted in favour of qualified workers (skill-biased) if the new skills are more costly to acquire than those required to operate with old machinery, while it will favour de-qualification (de-skilling) if the new skills can be acquired at a lesser cost than the skills or knowledge associated with pre-existing technologies.

Author et al. [6] and Machin and Van Reenen [56] argue that the widespread use of computers is a manifestation of skill biased technological change, which is responsible for the rise in the skill premium. The introduction of ICT will affect a smaller number of unskilled workers, but a greater number of workers with skills and knowledge complementary to innovation and ICT [20], [32], [38]. Other studies come to similar conclusions, thereby presenting a strong correlation between the use of ICT and the increase of worker skills ([12], [16]). As Landry et al. [55] conclude, routine jobs, above all, will be affected by significant levels of job loss. On the contrary, the increase in demand for qualified workers has accelerated in the last twenty-five years, especially from 1980 to the middle of the 1990s [24].

The core of the SBTC assumption postulates that new technological innovations complement, rather than replace high-skilled labor. The theory of complementarities postulates that two resources are complementary if their joint use yields an improvement in the value of each [4], [8], [59]-[61]. In accordance with this perspective, and with the concept of skill-biased technological change, it can be stated that skilled human resources and ICT resources are complementary [18], [35]. Consequently, firms that use one of these resources will show a propensity to use the other resource, jointly with the first, in order to take advantage of the resulting complementarities.

The expectation is that general education will help people to assimilate new technological information. If this is true, then better-educated workers will have a comparative advantage in using new technologies [12]. In general, the higher the level of education, the more an individual will access and use ICT at home, as well as in the workplace [63].

Arvanitis and Hollenstein [7] observe that the level of investment in ICT has been positively affected by the percentage of workers with a university education, and [3] notes that the level of education of users is positively related to the use of computers. In accordance with the skill-biased technical change perspective, the first hypothesis is defined as follows:

Hypothesis 1: Firms that use ICT have a higher level of educated workers.

A significant factor increasing the use of ICT is the existence of technological capabilities [29], [52]. The absorptive capacity, defined as the firm's ability to value, assimilate, and apply new knowledge [31], [75], allows firms to deal more adequately with new technologies. When a company wishes to acquire and use knowledge unrelated to its ongoing activity, it must develop absorptive capacity. Investment in human capital becomes more critical in solving the question of the obsolescence of the old abilities, this being the process required by innovation [76]-[77]. Data analyzed from the Annual Survey of Manufacturers, by [17], show an increase in skills required during the 1980s in the manufacturing sector, attributed in part to the introduction of ICT to job positions. Their results relate the spread of ICT both theoretically and empirically to the greater skills of workers. Similarly, [25], using data from the human resources survey of Information Week, reflect the fact that computerization goes hand-in-hand with an increase in skill requirements of the work force in order to maximise the use of the new technology. Spanos et al. [70] underline the need for multi-skilled personnel to exploit the advantages stemming from ICT adoption. In a study of workers' personal characteristics, Borghans and Ter Weel [20] found that skilled workers were more likely to use new information technologies.

Skill levels related to ICT can be acquired through different channels. Formal education offers at least some basic skills and certain kinds of specific skills related to ICT, although when it comes to specialized technologies and applications, specific ICT training related to the workplace tasks [65], sometimes offered by the suppliers themselves, may be needed [44]. It is interesting, therefore, to analyze not only the official training, but training oriented toward the acquisition of knowledge more directly linked to specific job activities [69]. The level of technological training of workers will be important for technology departments as well as for the rest of the firm [67].

On the basis of the preceding assertions, in line with the idea of ICT and human resource relationships, we define hypothesis 2:

Hypothesis 2: Firms that use ICT present a higher level of specific training

We suppose that the level of wages will be higher in firms using ICT. The underlying reasons for the increase in wage inequality in the OECD countries have been one of the most widely-studied questions during the last decade. Since many studies have found it difficult to account for the increase in the wages of skilled compared to unskilled labor (skill premium), skill-biased technological change has been proposed as the primary explanation [1]. This approach includes studies of the effects of technological change on the demand for skilled workers, through the variation in relative salaries, thereby obtaining empirical evidence about the increase in the wages of skilled versus unskilled workers [2], [12], [41], [46]. Additionally, the currently most widespread idea argues that a certain relationship exists between the use of new technologies and higher salary levels, once other variables that could affect them are controlled. This phenomenon is known as wage premium [54], [6], [20]. More efficient workers are associated with better salaries [57], since an increase in labor productivity due to technologies leads to an increase in wages. Therefore, highly-skilled workers using ICT are offered increasing wage premiums for their work, as a result of which the wage disparity between skilled and unskilled labor also increases. In accordance with the preceding assertions, the third hypothesis is defined as follows:

Hypothesis 3: Firms that use ICT have a higher level of wages.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 5 / ISSUE 1 / APRIL 2010 / 11-24

3 Research methodology

In this section, details are given regarding the methodology used to contrast the hypotheses that have been previously raised. In addition, there is a description of the database used, and the available information is presented, as well as the description of the size of the firm most relevant to the current study.

3.1 Research design

To test these hypotheses, diverse descriptive analyses are undertaken that allow the observation of the characteristics of firms that invest in ICT and the statistical significance of the differences with regard to firms that do not invest in these technologies. Included in the group of firms investing in ICT are those that have invested in equipment to process information during the year of the study, while the other group includes those firms that have not invested in these technologies during the same period.

3.2 Sample description

In order to perform the empirical analysis and verify our hypotheses, we use the Spanish Survey on Business Strategies (SBS). This survey is carried out annually by the Spanish Ministry of Industry, Tourism and Commerce, and the Public Enterprise Foundation (Fundación Empresa Pública – FUNEP). SBS has been selected as the source since it covers a wide and representative sample of Spanish manufacturing firms, operating in all industries and sectors on an annual basis [36]. This database is random and stratified according to industry sector and firm size. It includes all firms with more than 200 employees, and a representative sample of firms with more than 10 but fewer than 200 employees, selected by random statistical techniques. The survey includes information about markets, customers, products, employment, trade, outcomes, corporate strategy, human resources, and technological activities, among others. Furthermore, several publications have used this survey to focus on firm technological activities [37], [33]. Although the SBS is administered annually to firms, questions related to human resources and technology are only included in the questionnaire every four years. Moreover, some variables related to Information and Communication Technologies are not available for all years. Hence, we have used the information corresponding to the year 2002, which is the most recent year for which all the variables considered in the study are available. The total number of observations available for each year covers around 3,000 manufacturing firms; for 2002, it offers valuable information about 3,072 firms. After excluding firms with non-logical values, or lacking information on ICT use, the final sample comprises 1,269 manufacturing firms that will be used in our analysis. Of these, 738 invest in ICT, defined as computing or data-processing equipment.

4 Empirical analysis

In this section we present the results of the empirical study, illustrating some of the points raised above on the relationship between ICT investment policy and human resource management.

The data available from SBS enable us to define the variables needed to contrast the previous hypotheses.

4.1 Initial Descriptive Analysis

First, we analyze differences in the size of the firms that invest in ICT, and those that do not. It is probable that those firms that invest in ICT are larger, which permits them to take advantage of economies of scale and to overcome financial limitations in order to invest in these technologies. ICT investment provides the data to define the variable InvestICT, a dummy variable assuming a value of 1 for firms that invest in ICT, and 0 otherwise. As we can see in the following table (Table 1), the firms with ICT investment are of greater size than those that do not.

Regarding the total number of workers, it is observed that, on average, firms that do not invest in ICT have an average staff of 112 employees, while the average size of the staff of firms that invest in ICT is 255. The same pattern is observed in total sales volume, where for each monetary unit sold by firms that do not invest in ICT, the firms that do invest show sales of 2.5 monetary units. Finally, the differences are even greater in terms of the activity of the firms, where the total value of participation by firms that invest in ICT is almost triple the average value of activity by firms that do not invest in ICT.

To test hypothesis 1, relative to the relationship between the use of ICT and the educational level of the workers at the firm, we define a variable on education. On the one hand, the level of education is captured by the number of workers with university degrees (see Table 2); on the other hand, the education intensity has been computed as the ratio of workers with a university degree over the total workforce (see Table 3), distinguishing between three and five-year university degrees, as differentiated by the Spanish education system.

Table 2 and Table 3 present the main statistics of the educational variables for the total sample, distinguishing between the group of firms that invest in ICT, and the group of firms that do not invest in these technologies.

Table 1: Size of firms in the sample

		N	Mean	S.D.
Total number of workers	Firms that do not invest in ICT	531	112.30	234.98
	Firms that invest in ICT	738	255.36	434.43
	Total	1,269	195.50	371.16
Total sales*	Firms that do not invest in ICT	531	22,382.12	65,196.21
	Firms that invest in ICT	738	55,525.10	112,787.24
	Total	1,269	41,656.76	97,149.23
Total assets*	Firms that do not invest in ICT	514	21,278.86	73,427.35
	Firms that invest in ICT	727	58,394.24	207,358.76
	Total	1,241	43,021.71	166,551.77

Table 2: Educational statistics of the sample (I)

		N	Mean	S.D.
Number of workers with a five-year university degree	Firms that do not invest in ICT	531	6.25	19.50
	Firms that invest in ICT	738	22.76	76.74
	Total	1,269	15.85	60.40
Number of workers with a three-year university degree	Firms that do not invest in ICT	531	7.52	22.60
	Firms that invest in ICT	738	23.90	70.24
	Total	1,269	17.04	56.09
Number of workers without a university degree	Firms that do not invest in ICT	531	98.53	203.57
	Firms that invest in ICT	738	208.71	332.88
	Total	1,269	162.60	291.01

The standard deviation measures the dispersion or variability of data, and the mean of the distribution offers a measure of centrality. Through the analysis of the mean, in Table 2 we notice that all absolute variables present a higher value in the group of firms having invested in ICT than in the case of the firms without these investments. Firms that invest in ICT have a greater average number of workers in all the categories analyzed, both in the group of more highly trained workers, and among those without a university degree. As has already been seen in Table 1, firms that invest in ICT have a greater total number of workers, and as seen in Table 2, this numerical superiority holds over all educational levels. Therefore, to draw more exact conclusions regarding the connection between the adoption of ICT and the participation of different educational levels, it is necessary to correct for the size of the organization and present the data on the average qualification of related employees.

When we analyze the relative variables, we see that percentages of workers with a five- and a three-year university degree are higher in the group of firms that invest in ICT. However, the percentage of workers without a university degree is higher among firms that do not invest on ICT. These preliminary results are in accordance with hypothesis 1, which postulates that an adequate use of ICT requires that workers have certain skills that they can access from their university studies. Although these preliminary analyses offer initial evidence, we will investigate further in the following sections, where we will evaluate the statistical significance of these findings.

Hypothesis 2 pertains to the relationship between ICT investment and specific training. A positive relationship between ICT adoption and the necessity of offering specific training for workers is proposed, so that they might be capable of using the potential of ICT and improve the firm's results. To carry out a first analysis, we define two variables related to training. First, the relative training expenses per worker are measured by the total internal and external training expenses of the firm. Moreover, we define a variable that includes the specific training expenses of the firm. The values of the variables relative to the expenses for training collect the amount invested in these projects throughout the year, so that the values in the following table are expressed in euros per worker. We review these training expenses per worker in the total sample, distinguishing between firms that invest in ICT and firms that do not.

Table 3: Educational statistics of the sample (II)

		N	Mean	S.D.
Percentage of workers with a five-year university degree	Firms that do not invest in ICT	531	3.42%	0.05
	Firms that invest in ICT	738	6.42%	0.08
	Total	1,269	5.16%	0.07
Percentage of workers with a three-year university degree	Firms that do not invest in ICT	531	4.68%	0.09
	Firms that invest in ICT	738	7.72%	0.10
	Total	1,269	6.45%	0.10
Percentage of workers without a university degree	Firms that do not invest in ICT	531	91.90%	0.12
	Firms that invest in ICT	738	85.86%	0.15
	Total	1,269	88.39%	0.14

When we analyze the relative variables, we see that percentages of workers with a five- and a three-year university degree are higher in the group of firms that invest in ICT. However, the percentage of workers without a university degree is higher among firms that do not invest on ICT. These preliminary results are in accordance with hypothesis 1, which postulates that an adequate use of ICT requires that workers have certain skills that they can access from their university studies. Although these preliminary analyses offer initial evidence, we will investigate further in the following sections, where we will evaluate the statistical significance of these findings.

Hypothesis 2 pertains to the relationship between ICT investment and specific training. A positive relationship between ICT adoption and the necessity of offering specific training for workers is proposed, so that they might be capable of using the potential of ICT and improve the firm's results. To carry out a first analysis, we define two variables related to training. First, the relative training expenses per worker are measured by the total internal and external training expenses of the firm. Moreover, we define a variable that includes the specific training expenses of the firm. The values of the variables relative to the expenses for training collect the amount invested in these projects throughout the year, so that the values in the following table are expressed in euros per worker. We review these training expenses per worker in the total sample, distinguishing between firms that invest in ICT and firms that do not.

Table 4: Training statistics of the sample

		N	Mean	S.D.
Training expenses per worker	Firms that do not invest in ICT	530	36.33	135.54
	Firms that invest in ICT	732	112.78	408.53
	Total	1,262	80.67	325.39
ICT training per worker	Firms that do not invest in ICT	523	6.81	40.51
	Firms that invest in ICT	732	11.63	35.68
	Total	1,255	9.62	37.82

As we can see in Table 4, total training expenses per worker are more than three times higher in the group of firms that invest in ICT. On average, a firm that does not invest in ICT spends 36 euros per worker on training, as opposed to 113 euros spent by the firms that invest in ICT. Furthermore, ICT training expenses per worker in this group are nearly twice the expenses of the other group of firms (11.63 euros and 6.81 euros, respectively). These results are consistent with considerations by those authors who indicate that ICT requires more flexible human resources, capable of making optimum use of those technologies to respond more quickly to information about changes in demand [4]. Training received by the worker will provide the necessary capabilities to adapt more quickly to different requirements. These results are also consistent with the assertion made in hypothesis 2, where a positive relationship between ICT and training received by workers is set forth (although we will see additional statistical evidence in the following pages).

To test hypothesis 3, we measure the average level of wages using the total personnel expenses per worker at firm level, according to the annual statements of the firms. The variable related to personnel expenses collects wages and gross salaries, compensation, social contributions charged to the firm, contributions to complementary pension systems, and other social expenses incurred during the year, all in euros.

Therefore, the variable "Personnel expenses per worker" is expressed in euros per worker. As we can see in Table 5, average personnel expenses per worker are higher among the group of firms that invest in ICT, reaching 30,464 euros, compared to 24,227 euros, which is the median value among firms that do not invest in ICT. These results allow us to support a preliminary relationship between wages and ICT investment, as hypothesis 3 established, although the statistical significance of this relationship needs to be evaluated.

Table 5: Wage statistics of the sample

		N	Mean	S.D.
Personnel expenses per worker	Firms that do not invest in ICT	531	24,227.26	10,335.34
	Firms that invest in ICT	738	30,464.71	12,110.98
	Total	1,269	27,854.71	11,805.76

We also calculate relative variables on the duration of the contract of employment, and on the workers in research and development (R&D), which can be related to the diffusion of ICT [14].

Table 6: Other statistics of the sample

		N	Mean	S.D.
Percentage of temporary workers	Firms that do not invest in ICT	531	19.43%	0.22
	Firms that invest in ICT	738	16.61%	0.18
	Total	1,269	17.79%	0.20
Percentage of Production workers	Firms that do not invest in ICT	531	75.72%	0.16
	Firms that invest in ICT	738	65.89%	0.19
	Total	1,269	70.00%	0.18
Percentage of R&D workers	Firms that do not invest in ICT	529	0.80%	0.02
	Firms that invest in ICT	735	2.22%	0.05
	Total	1,264	1.63%	0.04

In table 6, we see that firms that invest in ICT present a lower level of temporary and production workers, whereas the percentage of R&D workers is nearly three times higher in the firms that do not invest in ICT. These results reflect the relationship between new technologies and the presence of highly qualified workers, with delegation responsibilities in the firm, and with a permanent connection to the firm. Proof of that is the lower proportion of temporary workers and of production, and the greater proportion of R&D workers among the firms that invest in ICT.

4.2 Statistical contrast of the hypotheses

Analyses carried out in the previous section allow the establishment of a first approximation of the magnitudes referring to the characteristics of human resources in firms that invest, and do not invest, in ICT. After the initial descriptive analysis, we apply the test to assess whether the differences between the two groups of firms are statistically significant. First, it is necessary to perform the relevant analysis to determine the suitability of applying parametric or non-parametric tests, paying attention to the normality of the distribution of the variables to be compared. To do so, the relevant tests to assess normality assumptions are applied. In Table 7, the normality Kolmogorov-Smirnov and Shapiro-Wilk tests are presented. The Kolmogorov-Smirnov (K-S) proof is a non-parametric proof, used to determine the goodness adjustment of two distributions of probability. Lilliefors' proof brings some improvements with respect to that of Kolmogórov-Smirnov to verify the normality of a distribution. The Shapiro-Wilk proof is also added to give a more potent alternation to the basic K-S proof.

Table 7: Normality tests (I)

		Kolmogorov-Smirnov (a)			Shapiro-Wilk		
		Statistic	gl	Sig.	Statistic	gl	Sig.
Percentage of workers with a five-year university degree	Firms that do not invest in ICT	0.26	531	0.000	0.67	531	0.000
	Firms that invest in ICT	0.22	738	0.000	0.70	738	0.000
Percentage of workers with a three-year university degree	Firms that do not invest in ICT	0.30	531	0.000	0.5465	531	0.000
	Firms that invest in ICT	0.22	738	0.000	0.68	738	0.000
Percentage of workers without a university degree	Firms that do not invest in ICT	0.24	531	0.000	0.69	531	0.000
	Firms that invest in ICT	0.17	738	0.000	0.79	738	0.000

(a) Lilliefors correction of the signification

The statistical significance of these contrasts indicates deviations from normality. Thus, normality of variables cannot be assumed in any group at level "p" (that is to say, p>0.05). To avoid the assumption of normality, implicit in the analysis of variance, we should use non-parametric tests for two independent samples of data. Specifically, we use the Mann-Whitney test to assess eventual significant differences between the means (Table 8).

Table 8: Statistics of contrast (I) (a)

	Mann-Whitney	Wilcoxon	Z	Asympt. Sig (bilateral)
Percentage of workers with a five-year university degree	134,803.50	276,049.50	-9.66	0.000
Percentage of workers with a three-year university degree	135,014.00	276,260.00	-9.62	0.000
Percentage of workers without a university degree	129,471.00	402,162.00	-10.38	0.000

(a) Variable of group: $Invest_{ICT}$

Results indicate that most of the variables present significant differences, statistically speaking, between both groups of firms. According to the asymptotical (bilateral) significance for each variable, we can conclude that the null hypothesis (that the mean of these variables are similar in both groups) should be rejected. That is to say, there is a significant correlation, statistically speaking, between ICT investment and the percentage of educated workers. We can show that technological change and workers' education are correlated. The percentage of educated workers is significantly higher in the group of firms using ICT. Consequently, we are prompted to accept hypothesis 1. Firms tend to adopt new technologies such as ICT at the same time as they employ workers with average qualifications superior to those in other firms that do not adopt those technologies.

Table 9: Normality tests (II)

		Kolmogorov-Smirnov(a)			Shapiro-Wilk		
		Statistic	gl	Sig.	Statistic	gl	Sig.
Training expenses per worker	Firms that do not invest in ICT	0.40	530	0.000	0.26	530	0.000
	Firms that invest in ICT	0.39	732	0.000	0.20	732	0.000
ICT training expenses per worker	Firms that do not invest in ICT	0.45	523	0.000	0.16	523	0.000
	Firms that invest in ICT	0.37	728	0.000	0.35	728	0.000
Personnel expenses per worker	Firms that do not invest in ICT	0.11	531	0.000	0.93	531	0.000
	Firms that invest in ICT	0.06	738	0.000	0.94	738	0.000

(a) Lilliefors correction of the signification

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 5 / ISSUE 1 / APRIL 2010 / 11-24

This paper is available online at
www.jtaer.com

Next, it is desirable to check the relationship between ICT and the training of the firm's workers (hypothesis 2), to then review differences in average salary levels between firms that invest in ICT, and firms that do not (hypothesis 3). In order to test hypothesis 2 and hypothesis 3, we have to test the normality assumptions to choose between parametric or non-parametric tests. For this, we once again apply the Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 9).

As shown in the previous table, the asymptotical significance indicates deviations from normality. Thus, it is necessary to apply non-parametric tests to analyze the differences between companies that invest in ICT, and those that do not.

According to the asymptotical (bilateral) significance for each variable (Table 10), we can conclude that the null hypothesis (that the mean of these variables are similar in both groups) must be rejected. The results show that the means in both groups are significantly different. As illustrated in Table 4, training expenses per worker, and ICT training expenses per worker are higher for ICT firms and, as we have just seen, these differences are statistically significant, which allows us to accept hypothesis 2. Both general training and ICT-specific training are positively correlated with the use of ICT. To achieve an appropriate use of the new technologies, it is necessary for workers to be capable of adapting to new situations and to be aware of the new needs and opportunities derived from the the use of these new technologies. Beyond the skills acquired through education, part of these capabilities are gained through on-the-job training, which is much closer to the specific needs and requirements of the firm. This training contributes to the absorptive capacity of the firm [31] and facilitates the use of new technologies, such as ICT.

Table 10: Statistics of contrast (II) (a)

	Mann-Whitney	Wilcoxon	Z	Asympt. Sig (bilateral)
Training expenses per worker	129,18	269,89	-11.37	0.000
Training expenses per worker	151,22	288,25	-8.44	0.000
Personnel expenses per worker	131,83	273,07	-9.96	0.000

(a) Variable of group: $Invest_{ICT}$

We observe that differences in personnel expenses per worker are also statistically significant, being higher in firms using ICT. This allows the validation of hypothesis 3, which establishes that firms that use ICT pay higher wages. These results are in line with studies finding that new technologies and wages are highly correlated [28], [26], [5]. For the Spanish case, [72] observes that those sectors in which the relationship of capital/work has increased the most, are those in which take-home pay has increased the most, confirming the existence of complementarities. Moreover, Juhn *et al.* [51] show that, for the US, after having accounted for education and experience, wage differentials have risen continuously since the early 1970s. The changes in demand and in the requirements of certain types of qualifications have contributed to generate inequalities between qualified and non-qualified work in terms of salaries [16], [22], [26], [53], [72].

Table 11: Normality tests (III) (a)

		Kolmogorov-Smirnov (a)			Shapiro-Wilk		
		Statistic	gl	Sig.	Statistic	gl	Sig.
Percentage of temporary workers	Firms that do not invest in ICT	0.19	531	0.000	0.81	531	0.000
	Firms that invest in ICT	0.18	738	0.000	0.81	738	0.000
Percentage of Production workers	Firms that do not invest in ICT	0.12	531	0.000	0.90	531	0.000
	Firms that invest in ICT	0.12	738	0.000	0.93	738	0.000
Percentage of R&D workers	Firms that do not invest in ICT	0.45	529	0.000	0.36	529	0.000
	Firms that invest in ICT	0.34	735	0.000	0.47	735	0.000

(a) Lilliefors correction of the signification

We can now show the differences in the percentage of temporary, production, and R&D workers, respectively. In Table 11 and Table 12, we present the normality tests and the non-parametric statistics to test the differences between ICT investors and non-ICT investors.

Statistical contrasts allow us to affirm that the mean of the percentage of temporary workers is similar in both groups, indicating that there are no differences in the precariousness of the labor contracts. Table 11 also allows us to reject the notion that the mean of the percentage of production and R&D workers is similar in both groups. Thus, we can affirm that there is a significant correlation, statistically speaking, between ICT investment and the percentage of blue-collar workers, and between ICT investment and the percentage of research and development workers. This is in accordance with the skill biased technological change; there are more qualified workers specialized in research and development, activities that offer a higher added value.

Table 12: Statistics of contrast (III) (a)

	Mann-Whitney	Wilcoxon	Z	Asympt. Sig (bilateral)
Percentage of temporary workers	187,595.50	460,286.50	-1.30	0.194
Percentage of Production workers	128,607.50	401,298.50	-10.46	0.000
Percentage of R&D workers	145,833.50	286,018.50	-9.21	0.000

a) Variable of group: $\text{Invest}_{\text{ICT}}$

5 Discussion

The results obtained from a sample of 1169 firms confirm that companies that invest in ICT employ larger numbers of educated and trained workers, which allows us to accept hypothesis 1. We can also accept hypothesis 2, which captures the relationship between ICT and specific training derived from the necessity to establish training processes in the workplace. Additionally, our results allow us to confirm hypothesis 3, showing that adoption of ICT is related to significantly higher levels of wages. In short, the conclusion can be drawn that companies investing in ICT employ more qualified and better paid workers, reinforcing the wage-inequality process.

Our results are broadly consistent with prior theoretical and empirical studies, and conform to the skilled-biased-technical-change framework, and the theory of complementarities. Moreover, among the few pieces of research that have been developed for the Spanish case, our work is consistent with [48], who indicate that the adoption of ICT is associated with organizational changes that aim for greater flexibility and participation of their workers. The combination of technological and human resource changes appears as a cluster of changes in modern firms, almost certainly due to their complementarities. Moreover, explanations based on organizational change can account for the observed rise in wage inequality, combined with skill-biased technical change.

We show the strong relationship between technology and diverse aspects of human resources, key elements in the competitiveness of the firm, which are complementary. Taking these findings into account, it is clear that managing technological change requires corresponding human resource policies.

Our findings will be of most interest to human resources practitioners, business strategists, and policy makers. For them, and at each decision-making level, it will be crucial to keep in mind the complementarities that exist between technological change stemming from ICT, and the strategic management of human resources, since each decision that refers to one aspect must be carried out while being mindful of relationships with the other elements, and of the repercussions that could occur. This obliges firms to look for an appropriate strategic adjustment between the management of human resources and that of ICT, without which the desired development promised by ICT will not be achieved.

As a major consequence of these findings, specific relations between organizational and technical elements can be better understood by more closely studying their fit, in the present and in the future. Furthermore, some suggestions for practitioners can be made. Organizations should take into account the importance of the relationships shown here, and enhance the skills of their workers at the same time as they invest in ICT. On the other hand, policy plays a key role in assuring that the potential advantages of ICT are realized. Public authorities should take into account the need to increase and improve workers' training and education, as a means of taking advantage of possible ICT benefits. These policies must foster the creation of a fertile environment for the acquisition of skills and competencies. Countries such as Spain, less developed than other Western countries, face the task of guaranteeing that the birth of new industries and business activities is not going to be hindered by a scarcity of manpower or insufficient skills [64]. As [15] highlight in a study of the Spanish case, policies to increase workforce education levels are necessary. According to the study, *Spain 2007* [39], inconsistent training of workers in ICT is one of the liabilities for Spanish firms that find themselves lagging behind European firms in this type of training. Nevertheless, public policies of training in ICT that are being currently carried out in Spain through the *Plan Avanza* of the Ministry of Industry, Tourism and Commerce [62], among others, are examples of the efforts being made in this area. At the same time, many business strategists and human resources practitioners are working together to offer flexible solutions that allow firms to adapt to, and confront, the changes demanded by the new competitive environment.

Finally, we should point out that the lack of certain specific information limits the scope of this research. Available longitudinal series would certainly be helpful to examine organizational characteristics over a period of several years, which would allow us to offer not only empirical evidence of the relationship between human resource characteristics and ICT, but also to explain the direction of causality direction among them. Future research lines will seek to improve the amount of data available to us. Nevertheless, our work here offers valuable evidence of significant relationships, through the statistical analysis of the differences between the firms investing in ICT, and those that do not. We can affirm that significant interdependencies exist, and that they should be taken into account.

6 Conclusion

In this paper, we set out to provide a more precise explanation of the relationship between ICT and diverse features characteristic of human resources in Spanish firms. There are many existing studies that present empirical evidence on the relationship between ICT investment and the human resource characteristics of the firm, using US datasets. In contrast, we enrich the set of studies in this field by offering evidence from a large sample of Spanish firms. Our paper presents the analysis of numerical data from a survey of business strategies, conducted in Spain, which allows us to add new empirical evidence to the rather limited existing literature pertaining to this country.

Our results indicate that the current digital revolution is slanted in favour of qualified workers, who at the same time receive more training on the job and reach superior average salary levels. Our statistical analyses indicate that these workers have a greater relative participation in the group of firms that incorporate new technologies. Specifically, it is observed that firms adopting ICT require qualified and well-trained staff, capable of responding to the demands of flexibility and adaptation to new technologies, and to the new environments in which they are implemented, in order to achieve higher levels of productivity and efficiency. In such environments, greater attention must be paid to questions of apprenticeship and continued improvement, since workers must adapt to changing situations imposed by new technologies, making specific investments to acquire knowledge adapted to the new necessities.

Additionally, we observe that firms adopting ICT offer average salary levels superior to those offered by the firms who make no such investments. This reinforces the idea that the workers who use ICT attain higher levels of productivity than are reflected in the salaries they receive as compensation for this efficiency. Finally, it is necessary to pay special attention to the differences in employability between the technology-savvy “haves” and the “have-nots,” a phenomenon known as the “digital divide.” Policy makers must direct their efforts to the bridging of this digital divide by promoting the adaptation by all workers of the necessary tools for the new knowledge society.

Acknowledgments

This paper was developed under the objectives of the CREVALOR Research Group (DGA-Spain), and it was funded by MEC Research Project SEJ2006-14685 and the “Cátedra de la Empresa Familiar” (University of Zaragoza).

References

[1] J. D. Acemoglu, Why do new technologies complement skills? Directed technical change and wage inequality, Quarterly Journal of Economics, vol. 113, no. 4, pp. 1055-1089, 1998.
[2] P. Aghion, E. Caroli, and C. García Peñalosa, Inequality and economic growth: The perspective of the new growth theories, Journal of Economic Literature, vol. 37, no. 4, pp. 1615-1660, 1999.
[3] S. S. Al-Gahtani, Computer technology acceptance success factors in Saudi Arabia: An exploratory study, Journal of Global Information Technology Management, vol. 7, no. 1, pp. 5-29, 2004.
[4] M. C. Anderson, R. D. Banker, and S. Ravindran, Value implications of investments in information technology, Management Science, vol. 52, no. 9, pp. 1359-1376, 2006.
[5] G. R. Arabsheibani, J. M. Emami, and A. Marin, The impact of computer use on earnings in the UK, Scottish Journal of Political Economy, vol. 51, no. 1, pp 82-94, 2004
[6] E. Arnal, W. Ok, and R. Torres, Knowledge, work organization and economic growth, OECD, Directorate for Employment, Labour and Social Affairs, no. 50, France, 2001.
[7] S. Arvanitis, and H. Hollenstein, The Determinants of the Adoption of Advanced Manufacturing Technology, Economics of Innovation and New Technology, vol. 10, no. 5, pp. 377-714, 2001.
[8] S. Athey, and S. Stern, An empirical framework for testing theories about complementarities in organizational design, NBER Working Paper 6600, 1997.
[9] M. Attaran, Exploring the relationship between technology and business process reengineering, Information & Management, vol. 41, pp. 585-596, 2004.

[10] D. L. Autor, F. Katz, and A. B. Krueger, Computing inequality: Have computer changed the labor market?, Quarterly Journal of Economics, vol. 113, no. 4, pp. 1169-1213, 1998.
[11] D. L. Autor, F. Levy, and R. Murnane, The skill content of recent technological change: An empirical exploration, Quarterly Journal of Economics, vol. 18, no. 4, pp.1279-1333, 2003.
[12] A. Bartel, and F. Lichtenberg, The comparative advantage of educated workers in implementing new technology, Review of Economics and Statistics, vol. 69, no. 1, pp. 1-11, 1987.
[13] A. Bartel, C. Ichniowski, and K. Shaw, How does information technology affect productivity? Plant-level comparisons of product innovation, process improvement and worker skills, Quarterly Journal of Economics, vol. 122, no. 4, 1721-1758, 2007.
[14] G. Battisti, H. Hollenstein, P. Stoneman, and M. Woerter, Inter and intra firm diffusion of ICTs in the United Kingdom (UK) and Switzerland (CH): An internationally comparative study based on firm-level data, Economics of Innovation and New Technology, vol. 16, no. 8, pp. 669-687, 2007.
[15] A. Bayo, and F. Lera, A firm-level analysis of determinants of ICTs adoption in Spain, Technovation, vol. 27, no. 6-7, pp. 352-366, 2007.
[16] E. Berman, J. Bound, and S. Machin, Implications of skill-biased technological change: International evidence, Quarterly Journal of Economics, vol. 113, no. 4, pp.1244-1279, 1998.
[17] E. Berman, J. Bound, and Z. Griliches, Changes in the demand for skilled labor within U.S. manufacturing: Evidence from the Annual Survey of Manufactures, Quarterly Journal of Economics, vol. 109, no. 2, pp. 367-398, 1994.
[18] E. R. Berndt, C. J. Morrison, and L. S. Rosenblum, High-tech capital formation and labor composition in U.S. manufacturing industries: an explanatory analysis, Journal of Econometrics, vol. 65, no. 1, pp. 9-43, 1994.
[19] L. Borghans, and B. Ter Weel, The diffusion of computers and the distribution of wages, European Economic Review, vol. 51, no. 3, pp. 715-748, 2007.
[20] L. Borghans, and B. Ter Weel, Computers, skills and wages, Applied Economics, vol. 35, no. 14, pp. 1561-1576.
[21] L. Borghans, and B. Ter Weel, The division of labour, worker organisation, and technological change, Economic Journal, vol. 116, no. 509, pp. F45-F72, 2006.
[22] J. Bound, and G. Johnson, Changes in the structure of wages in the 1980's: An evaluation of alternative explanations, American Economic Review, vol. 82, no. 2, pp. 371-392, 1992.
[23] H. Braverman, Labor, and Monopoly Capital: The Degradation of Work in the Twentieth Century, New York: Monthly Review Press, 1974.
[24] T. F. Bresnahan E. Brynjolfsson, and L. Hitt, Information Technology, workplace organization and the demand for skilled labor: Firm-level evidence, The Quarterly Journal of Economics, vol. 117, no. 1, pp. 339-376, 2002.
[25] E. Brynjolfsson, and L. Hitt, The Productive Keep Producting, InformationWeek, no. 545, pp. 38-52, 1995.
[26] D. Card, and T. Lemieux, Can falling supply explain the rising return to collage for younger men? A cohort-based analysis, Quarterly Journal of Economics, vol. 116, no. 2, pp. 705-746, 2001.
[27] E. Caroli, and J. Van Reenen, Skill-biased organizational change? Evidence from a panel of British and French establishments, Quarterly Journal of Economics, vol. 116, no. 4, pp. 1449-1492, 2001.
[28] L. Chennells, and J. Van Reenen, Technical change and the structure of employment and wages: A survey on the microeconometric evidence, in Productivity, inequality and the digital economy (Greenan, N., Y. L'Horty and J. Mairesse, Eds.). MIT Press, 2002, pp. 175-224.
[29] P. Chwelos, I. Benbasat, and A. S. Dexter, Research report: Empirical test of an EDI adoption model, Information Systems Research, vol. 12, no. 3, pp. 304-321, 2001.
[30] Commission of the European Communities, i2010 -Annual Information Society Report 2007, Brussels, Belgium, 2007.
[31] W. M. Cohen, and D. A. Levinthal, Absorptive capacity: A new perspective on learning and innovation, Administrative Science Quarterly, vol. 35, no. 1, pp. 128-152, 1990.
[32] B. P. Cozzarin, and J. C. Percival, Complementarities between organisational strategies and innovation, Economics of Innovation and New Technology, vol. 15, no. 3, pp. 195-217, 2006.
[33] N. Díaz-Díaz, I. Aguilar-Díaz, and P. De Saá-Pérez, La incidencia de la adquisición y generación de conocimiento en la innovación, Revista Europea de Dirección y Economía de la Empresa, vol. 17, no. 1, pp. 57-78, 2008.
[34] M. Doms, T. Dunne, and K. R. Troske, Workers, wages, and technology, Quarterly Journal of Economics, vol. 112, no. 1, pp.255-290, 1997.
[35] M. Falk, and K. Seim, Workers´ skill level and information technology: A censored regression model, International Journal of Manpower, vol. 22, no. 1-2, pp. 98-120, 2001.
[36] J. C. Fariñas, and J. Jaumandreu. Diez años de encuesta sobre estrategias empresariales (ESEE), Economía Industrial, no. 329, pp. 29-42, 1999.
[37] Z. Fernández, and M.J. Nieto, The Internet: Competitive strategy and boundaries of the firm, International Journal of Technology Management, vol. 35, no. 1-2-3-4, pp. 182-195, 2006.
[38] C. Francalanci, and H. Galal, Information technology and worker composition: Determinants of productivity in the life insurance industry, MIS Quarterly, vol. 22, no. 2, pp. 227-241, 1998.
[39] Fundación Orange, eEspaña 2007: Informe anual sobre el desarrollo de la sociedad de la información en España, Madrid: Fundación Orange, 2007.
[40] Fundación Retevisión, eEspaña 2001: Informe Anual sobre el Desarrollo de la Sociedad de la Información en España, Madrid: Fundación Retevisión, 2001.
[41] O. Galor, and O. Moav, Ability-biased technological transition, wage inequality, and economic growth, Quarterly Journal of Economics, vol. 115, no. 2, pp. 469-497, 2000.

[42] E. García-Canal, A. Rialp, and J. Rialp, Tecnologías de la información y comunicación (TIC) y crecimiento de la empresa, Información Comercial Española, ICE: Revista de economía, no. 838, pp. 125-145, 2007.
[43] C. Goldin, and L. Katz, The origins of technology-skills complementarity, Quarterly Journal of Economics, vol. 113, no. 2, pp. 693-732, 1998.
[44] B. H. Hall, and B. Khan, Adoption of New Technology, in Jones, Derek C. Handbook of Economics in the Electronic Age, Academic Press. San Diego, CA, 2003.
[45] A. Hargadon, Technology brokering and innovation: linking strategy, practice, and people, Strategy and Leadership, vol. 33, no. 1, pp. 32-36, 2005.
[46] M. Hoskins, The effects of sectorial and technological changes on the skill composition of employment in the United Kingdom 1951-91, Economics Letters, vol. 69, no. 1, pp. 101-107, 2000.
[47] J. J. P. Hsieh, A. Rai, and M. Keil, Understanding digital inequality: Comparing continued use behavioral models of the socio-economically advantaged and disadvantaged, MIS Quarterly: Management Information Systems, vol. 32, no. 1, pp. 97-126, 2008.
[48] E. Huerta (Ed.), J. A. Bayo, C. García, and J. Merino, Los Desafíos de la Competitividad: La Innovación Organizativa y Tecnológica en la Empresa Española, Bilbao: Fundación BBVA, 2003.
[49] L. W. Hunter, and J. J. Lafkas, Opening the box: Information technology, work practices, and wages, Industrial & Labor Relations Review, vol. 56, pp. 224–243, 2003.
[50] Z. Hussain, J. Wallace, and N. E. Corneliuset, The use and impact of human resource information systems on human resource management professionals, Information & Management, vol. 44, pp. 74–89, 2007.
[51] C. Juhn, K. M. Murphy, and B. Pierce, Wage inequality and the rise in returns to skill, Journal of Political Economy, vol. 101, no. 3, pp. 410-442, 1993.
[52] H. Katrak, The private use of publicly funded industrial technologies in developing countries: Empirical test for an industrial research institute in India, World Development, vol. 25, no. 9, pp. 1541-1551, 1997.
[53] L. F. Katz, and K. M. Murphy, Changes in relative wages, 1963-87: Supply and demand factors, Quarterly Journal of Economics, vol. 107, no. 1, pp. 35-78, 1992.
[54] A. Krueger, How computers have changed the wage structure: Evidence from microdata, Quarterly Journal of Economics, vol. 107, no. 1, pp. 33-60, 1993.
[55] B.J.L. Landry, S. Mahesh, and S. Hartman, The changing nature of work in the age of e-business, Journal of Organizational Change Management, vol. 18, no. 2, pp. 132-144, 2005.
[56] S. Machin, and J. Van Reenen, Technology and changes in skill structure: Evidence from seven OECD countries, The Quarterly Journal of Economics, vol. 113, no. 1, pp. 1215-1244, 1998.
[57] A. Martín, and L. Moreno, Los retos de la productividad industrial, Papeles de Economía Española, no. 112, pp. 90-105, 2007.
[58] P. Milgrom, and J. Roberts, Economics, Organization and Management, Englewood Cliffs: Prentice Hall, Inc., 1992.
[59] P. Milgrom, and J. Roberts, The economics of modern manufacturing: Technology, strategy, and organization, American Economic Review, vol. 80, no. 3, pp. 511-528, 1990.
[60] P. Milgrom, and J. Roberts, Complementarities and fit: Strategy, structure and organizational change in manufacturing, Journal of Accounting and Economics, vol. 19, no. 2-3, pp.179-208, 1995.
[61] P. Milgrom, Y. Qian, and J. Roberts, Complementarities, momentum, and evolution of modern manufacturing, American Economic Review, vol. 81, no. 2, pp. 84-88, 1991.
[62] Ministerio de Industria, Turismo y Comercio (2009, September). La Sociedad en Red: Informe Anual de la Sociedad de la Información en España 2008. [Online]. Available: http://www.red.es/media/registrados/2009-09/1252574705496.pdf?aceptacion=3dc8a66f8373c934fa1fbbba9d844c1d
[63] P. Montagnier, E. Muller, and G. Vickery. The Digital Divide: Diffusion and use of ICTs, Information, Computer and Communications Policy Division Directorate for Science, Technology and Industry, OECD, Paris, 2002.
[64] OECD, Information Technology Outlook 2002, OECD, Paris, 2002.
[65] OECD, ICTs diffusion to business: Peer review. Country report: The Netherlands, Directorate for Science, Technology and Industry Committee for Information, Computer and Communications Policy, OECD, Paris, DSTI/ICCP/IE(2004)4/FINAL, 2005.
[66] W. J. Orlikowski, Improvising Organizational transformation over time: A situated change perspective, Information Systems Research, vol. 7, no. 1, pp. 63-92,1996.
[67] G. Premkumar, and W. R. King, Organizational characteristics and information systems planning: An Empirical Study, Information Systems Research, vol. 5, no. 2, pp. 75-109, 1994.
[68] J. Rockart, and J. Short, IT in the 1990´s: Managing organizational interdependence, Sloan Management Review, vol. 30, no. 2, pp. 7-17, 1989.
[69] M. Sacristán-Díaz, and F.J. Quirós, Technological innovation and Employment: Data From a Decade in Spain, International Journal of Production Economics, vol. 75, no. 3, pp. 245-256, 2002.
[70] Y. E. Spanos, G.P. Prastacos, and A. Poulymenakou, The relationship between information and communication technologies adoption and management, Information and Management, vol. 39, no. 8, pp. 659-675, 2002.
[71] J. A. Torbin, and A.H. Segars, The impact of IT on decision structure and firm performance: Evidence from the textile and apparel industry, Information and Management, vol 39, no. 2, pp 85-100, 2001.
[72] X. Torres, Dispersión salarial y cambio tecnológico en la industria española, Investigaciones Económicas, vol. 26, no. 3, pp. 551-571, 2002.
[73] A. L. Vinding, Absorptive capacity and innovative performance: A human capital approach, Economics of Innovation and New Technology, vol. 15, no. 4-5, pp. 507–517, 2006.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 5 / ISSUE 1 / APRIL 2010 / 11-24

This paper is available online at
www.jtaer.com

[74] World Economic Forum, The Global Information Technology Report 2008-2009, New York: Oxford University Press, 2009.
[75] Y. Xue, H. Liang, and W. R. Boulton, Information technology governance in information technology investment decision processes: The impact of investment characteristics, external environment, and internal context, MIS Quarterly: Management Information Systems, vol. 32, no. 1, pp. 67-96, 2008.
[76] S. A. Zahra, and G. George, Absorptive capacity: A review, reconceptualization and extension, Academy of Management Review, vol. 27, no. 2, pp. 185-203, 2002.
[77] T. Zwick, The impact of ICTs investment on establishment productivity, National Institute Economic Review, vol. 184, no. 1, pp. 99-110, 2003.